Rijkswaterstaat
Ministry of Infrastructure and the Environment

Monitoring needs ageing infrastructure

COST workshop
September 28 2015

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Introduction

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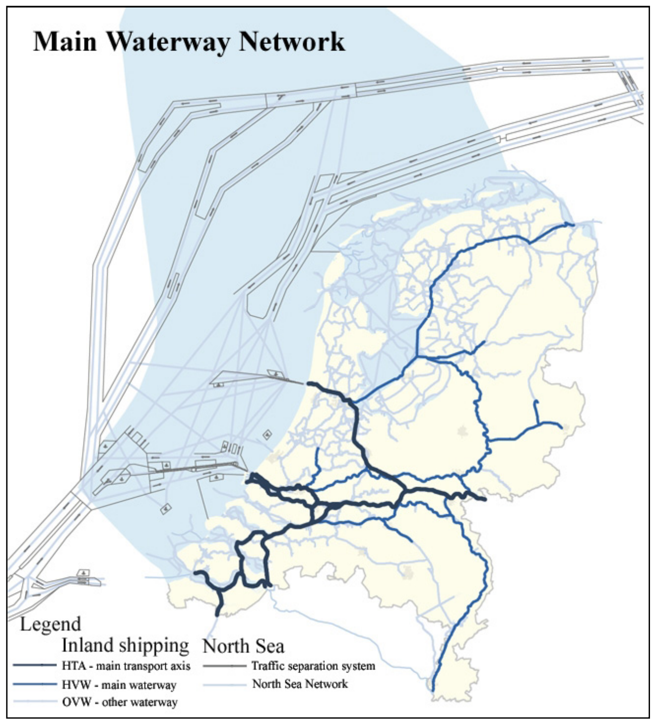
Outline

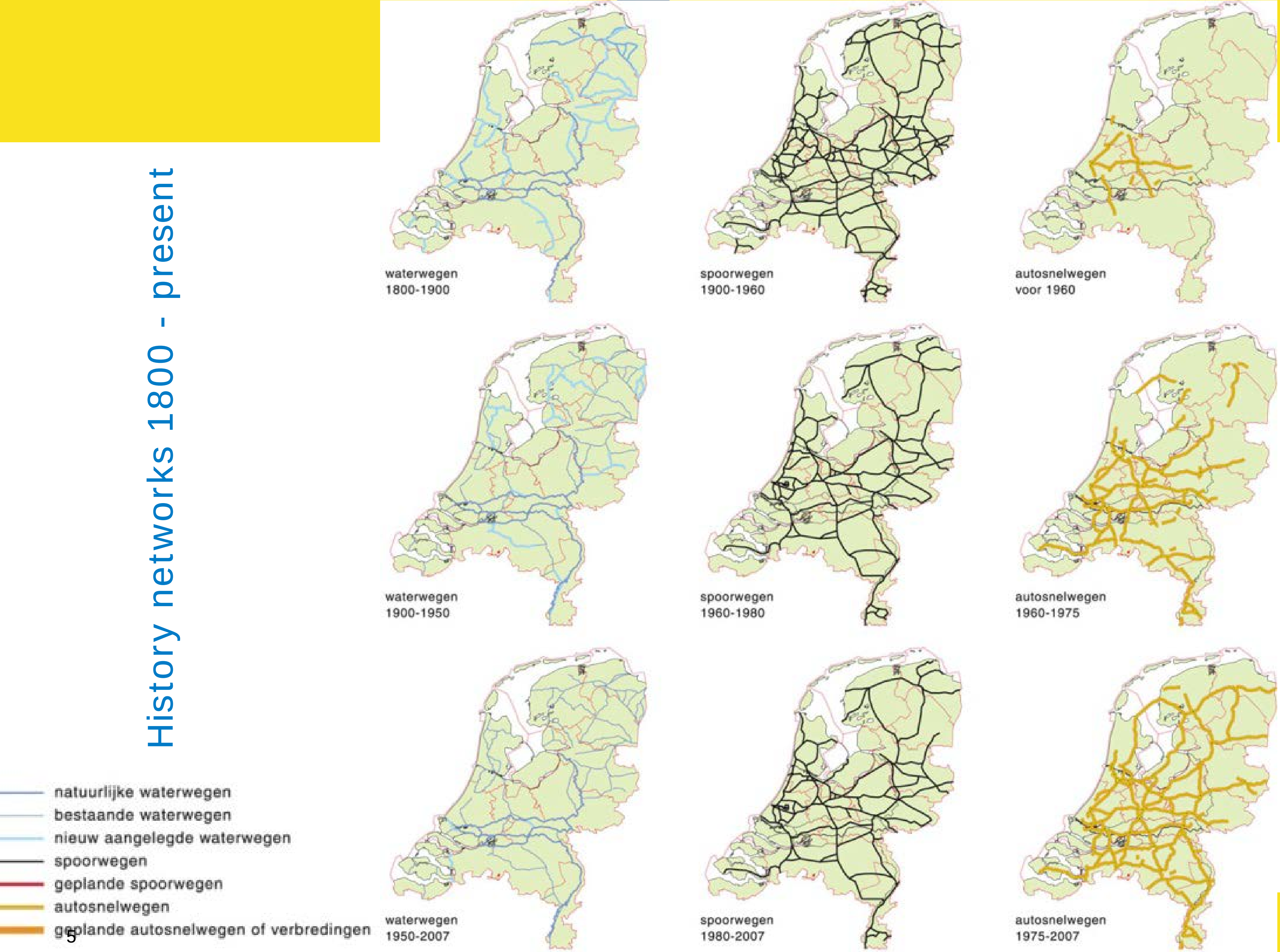
- Assets Rijkswaterstaat
- Road expansion
- End of service life
- Examples monitoring
- Conclusions

Assets Rijkswaterstaat

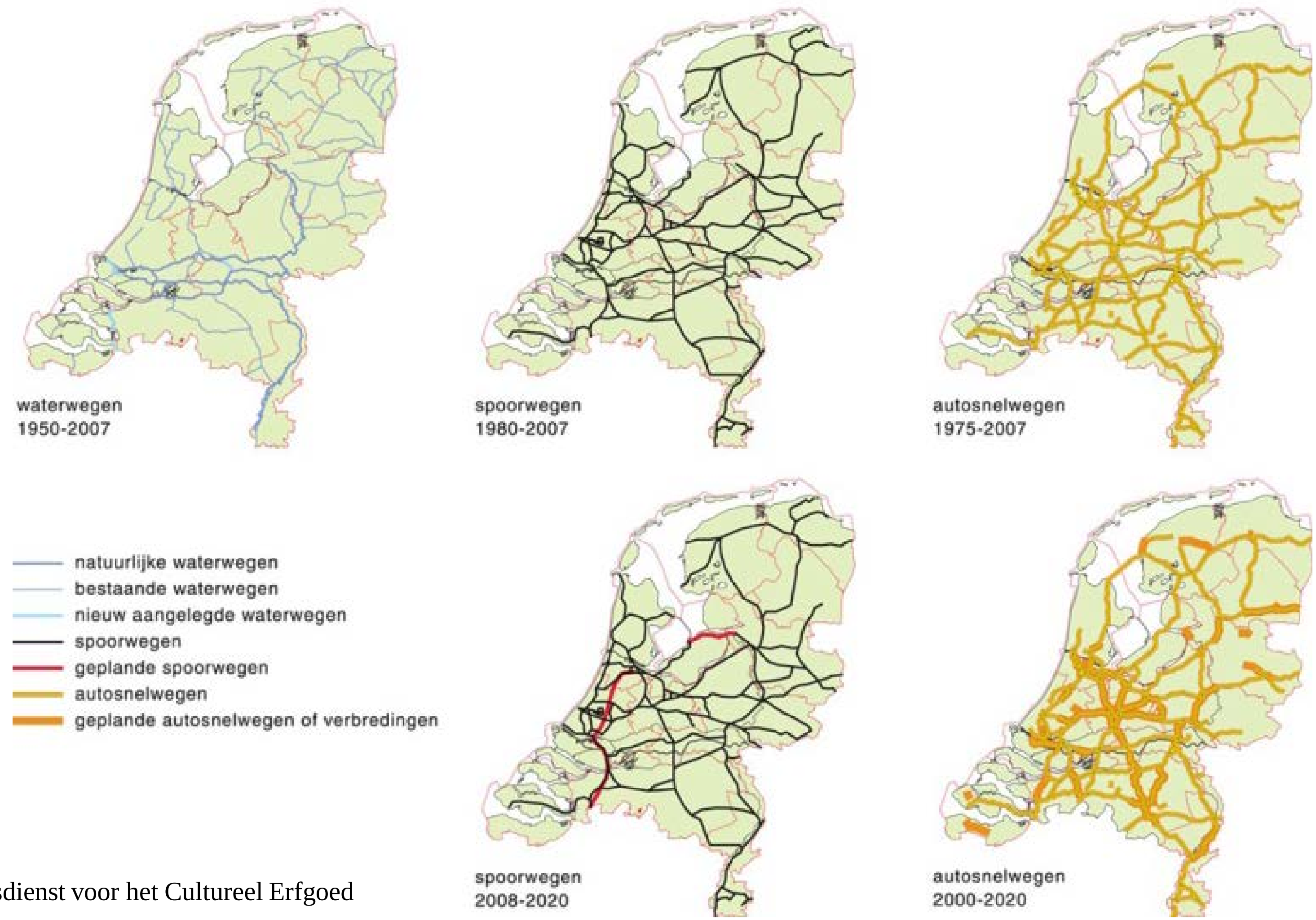
Rijkswaterstaat manages three National Infrastructure Networks



History networks 1800 - present



Development networks in near future



Source: Rijksdienst voor het Cultureel Erfgoed

Development infrastructure networks

- Networks for rail, road and inland water transport have matured
- No large scale new links
- Expansion within existing network
- Interlocking, connecting links as well city rings

National highways network

- 3,075 km highway, of total 60 000 km road outside cities
  - of which 2,400 km motorway,
  - and 1,259 km with traffic management systems,
    - 1 national and 5 regional traffic control centres
    - 421 dynamic route info signs
    - 90 rush-hour lanes (335 km)
- Traffic movements
  - 45 % (vehicle-kilometers)

Structures in main road network

Type	number
Viaduct over highway	999
Viaduct in highway	1779
Movable bridges	58
Bridge - concrete small	600
Bridge - concrete large	54
Bridge - steel	31
Tunnels	22
Aqueducts	12
Total	3555

Development infrastructure networks

Issues:

- Re-use of existing “construction mass”
- Intensification use
- Higher standards for reliability and safety
- Environmental aspects; higher loads due to climate change, less impact: (low energy, low carbon => sustainable infrastructure
- Hardware: ITS, tunnels, covered roads, noise screens
- Materials: noise reducing porous asphalt, high strength concrete, FRP

Increase ICT in infrastructure networks

Increase ICT in infrastructure networks

- Hardware: ITS, tunnels, controll centers
- Software: traffic control/ guidance:
  - now external, manual interface
  - in future in-car, automatic

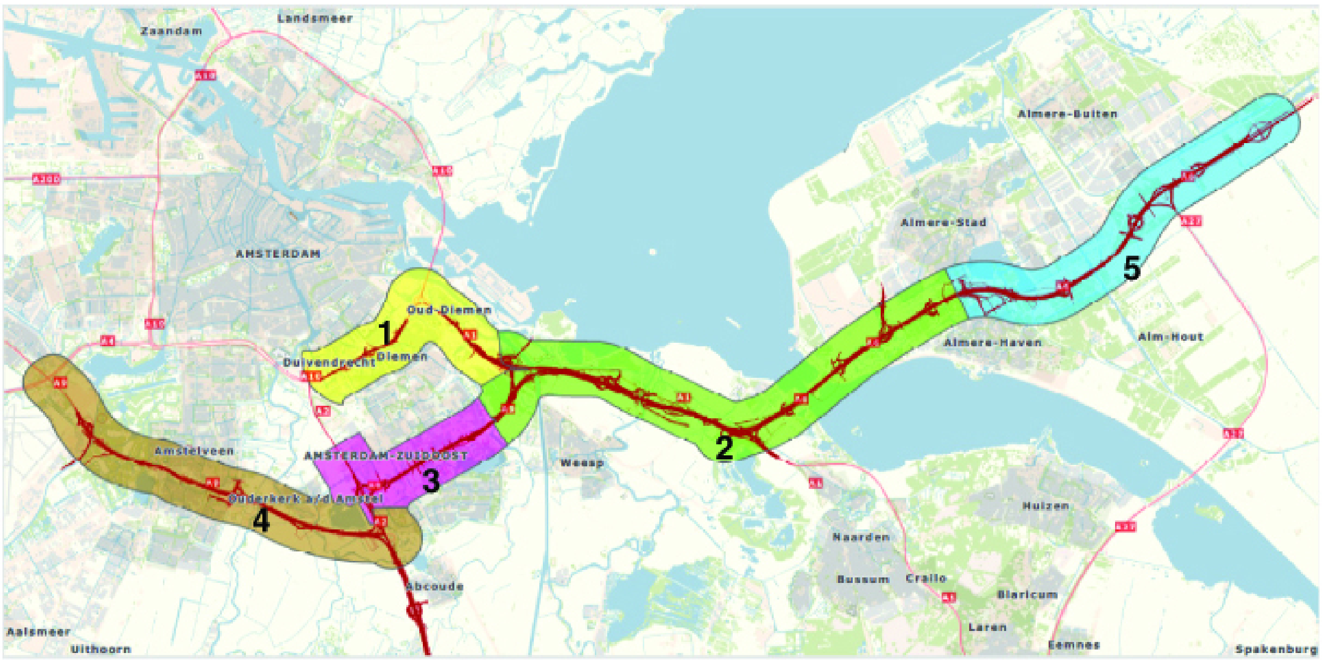
Demands Netherlands main road network

Less hindrance for users (no traffic jams):

- Construction forms and logistics -> prefab
- Work in off-peak hours
- Road lane layout during maintenance; 4- 0 systems etc
- Publicity
- Free public transport
- “Spitsmijden”; bonus for not driving during peak hours

Examples 2 large road expansion projects

Schiphol ✈ - Amsterdam 🏭 - Almere 🏠



Traffic jams in the Netherlands Amsterdam region

Commuters from Almere. Almere is only 38 years old and one of the fastest growing cities in Europe and has the ambition to become the fifth largest city (where it is currently the seventh largest city) in the Netherlands over the next twenty years. Currently, Almere is a city with over 195,000 inhabitants.

Schiphol ✈ - Amsterdam - Almere

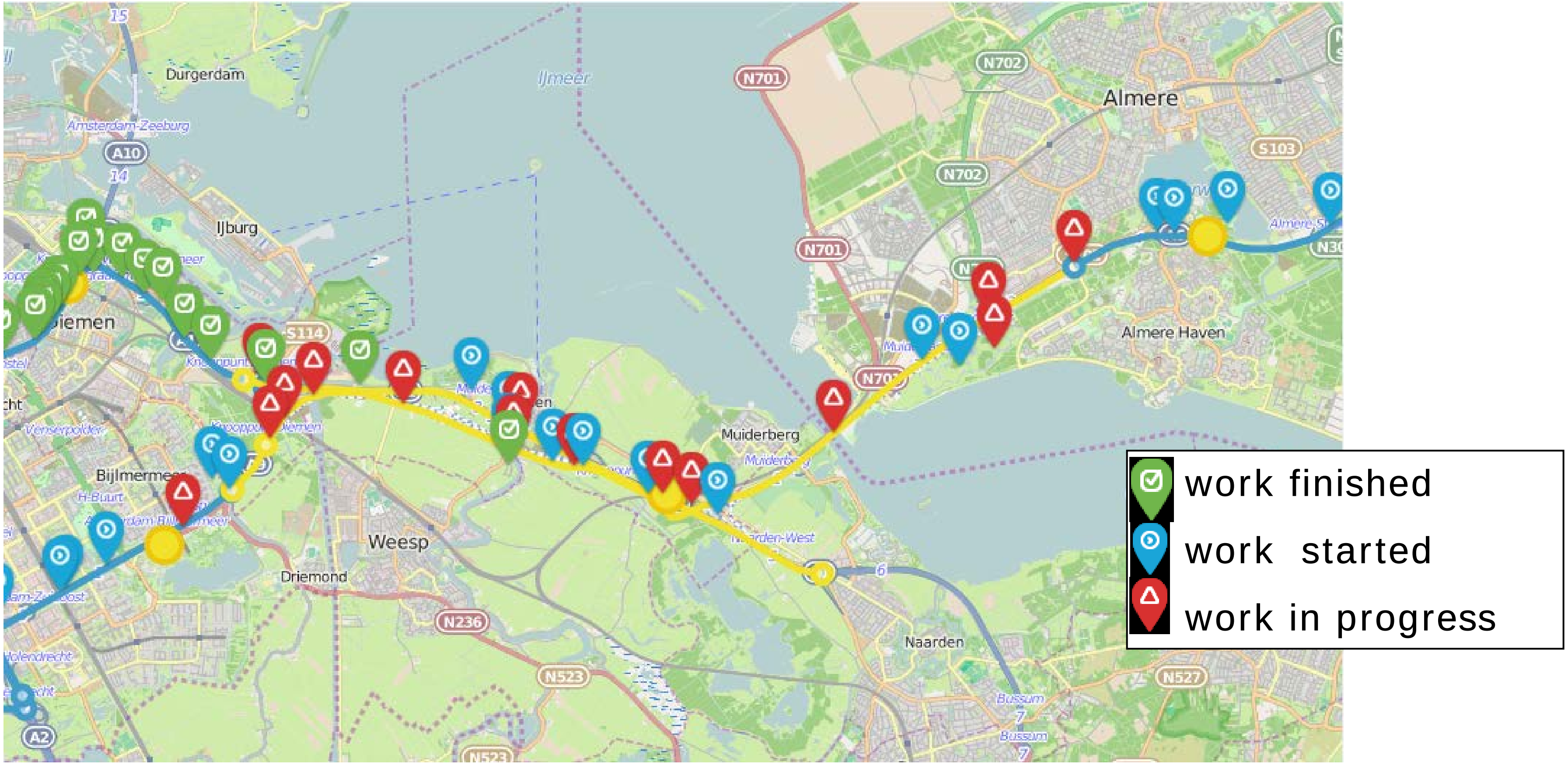
What Rijkswaterstaat wants: better traffic flow and shorter travel time. This means expanding the capacity of the A1 – A6 – A9 – A10

- 63 km road expansion
- renovation of 5 major motorway junctions
- 130 new or adapted constructions
- renovation of 3 railway crossings
- Renovation of 100 viaducts

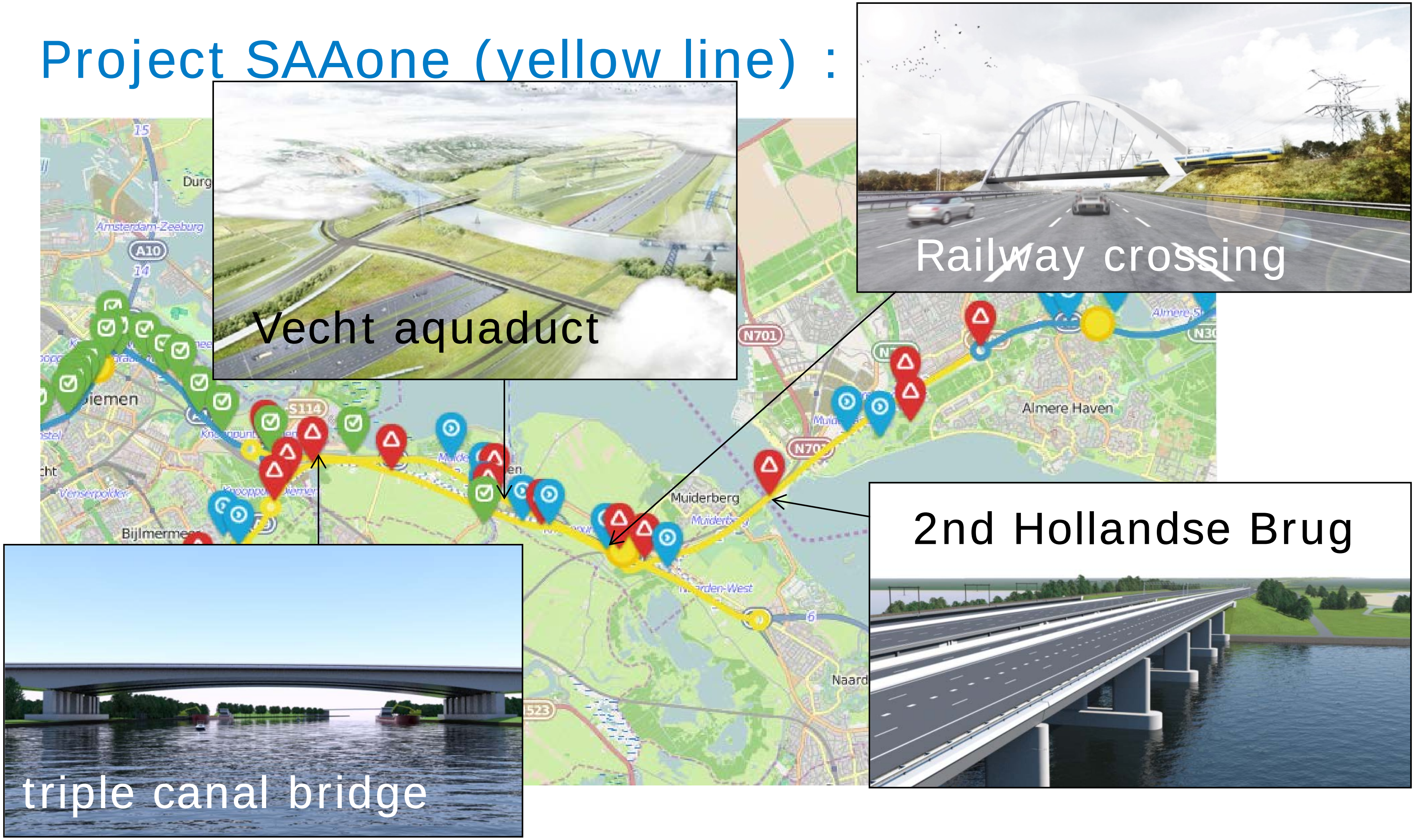
At the same time we take the opportunity to improve the quality of life of those living near these motorways:

- 125 km noise reducing asphalt
- 36 km noise screens
- a (land)tunnel in the A9 connecting residential areas
- Constructing the A9 partly below the surface Amstelveen
- new eco crossings

Project SAAone (yellow line) : 14 objects

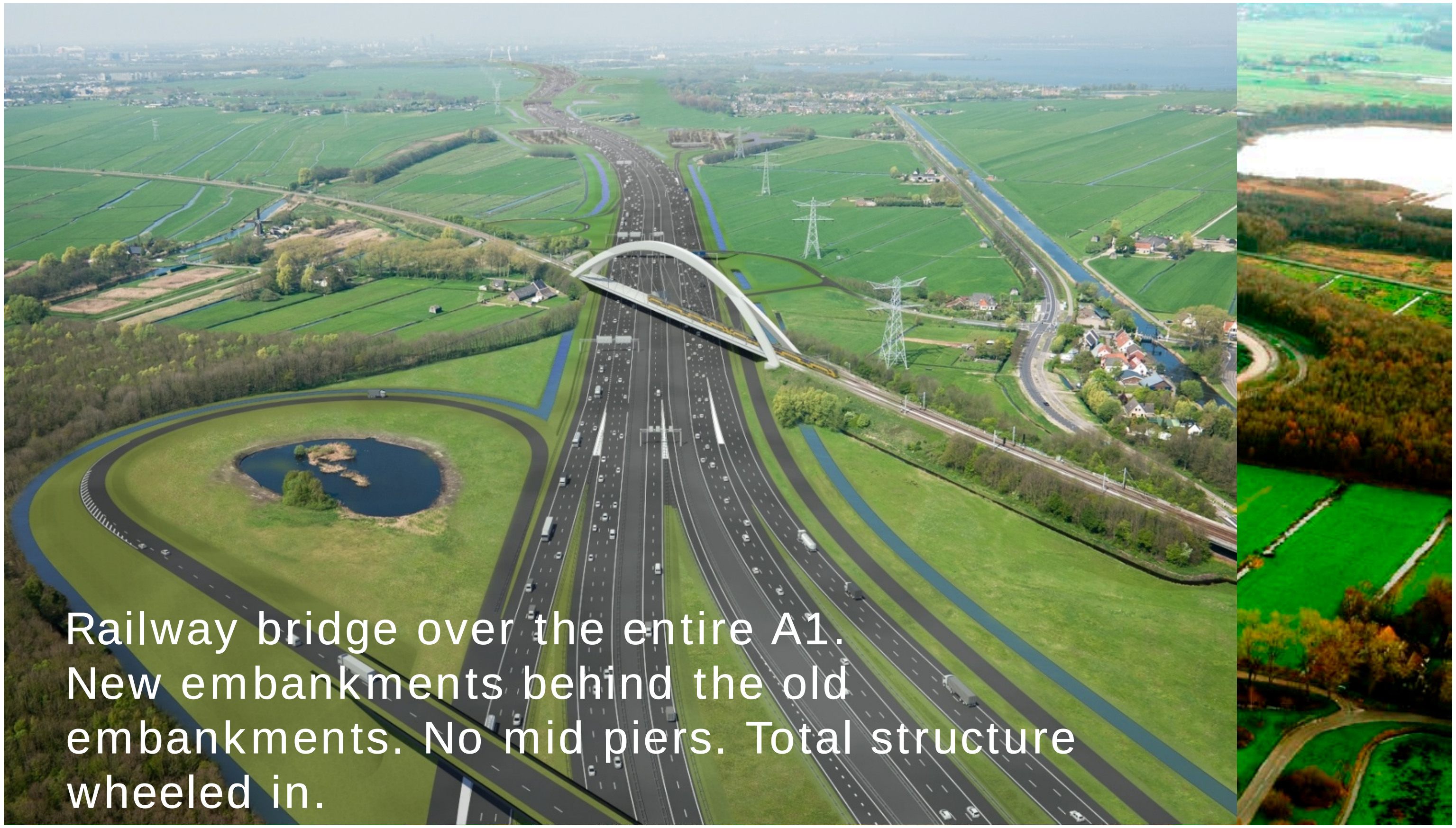


Project SAAone (yellow line) :



Special solutions to reduce traffic hinder

Special solutions to reduce traffic hinder



Railway bridge over the entire A1.
New embankments behind the old embankments. No mid piers. Total structure wheeled in.

Prefab bridge decks

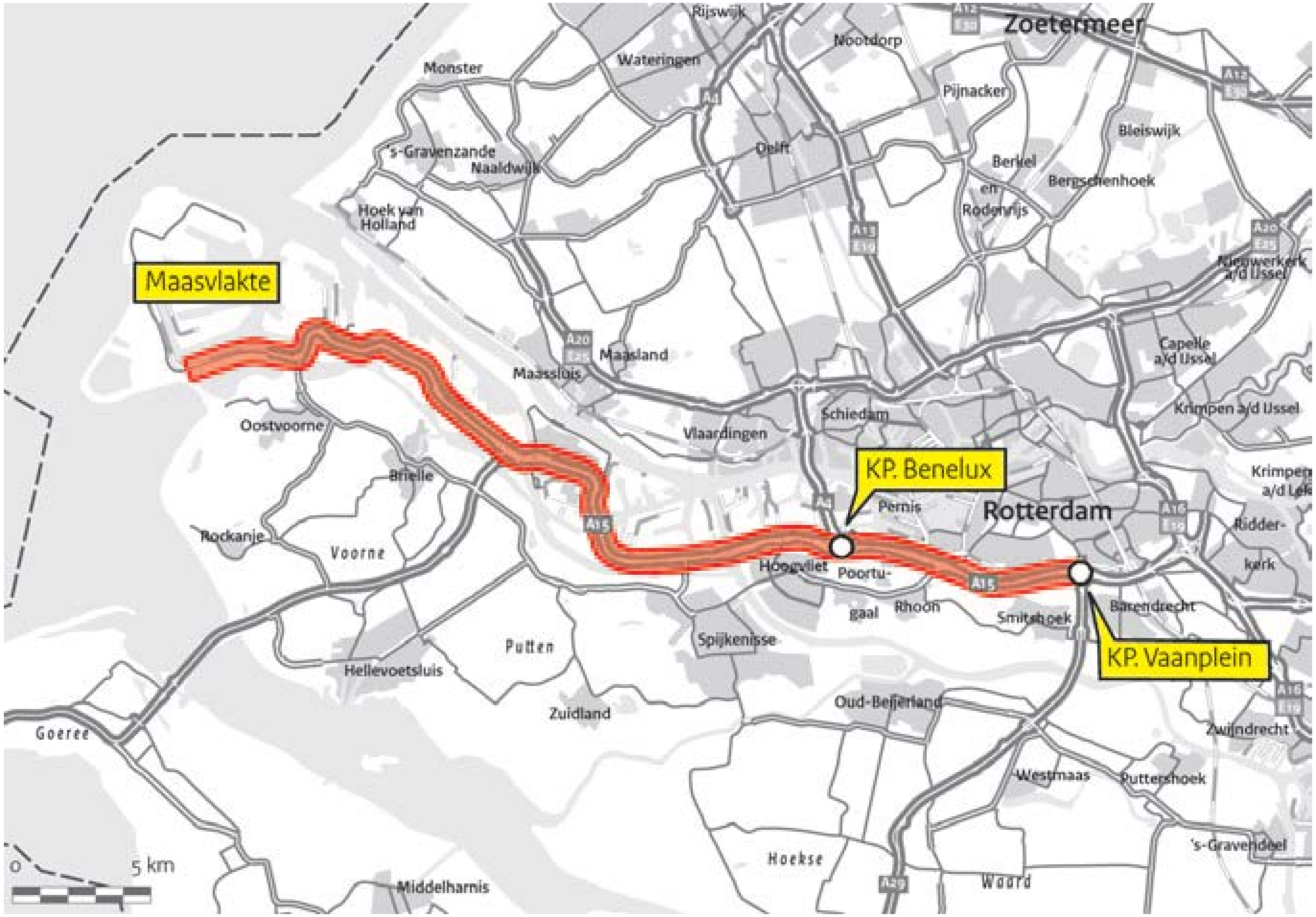
Hollandse bridge.

7 x 50 meter spans : prefab I-beams with in situ concrete top layer.

Traffic jams in the Netherlands
Rotterdam region

Heavy traffic to and from the Rotterdam harbour. Major land claiming projects on the sea (1st and 2nd Maasvlakte) in order to expand the harbour with deep sea container terminals and quays for the petrochemical industry.

Maasvlakte - Vaanplein



Maasvlakte - Vaanplein

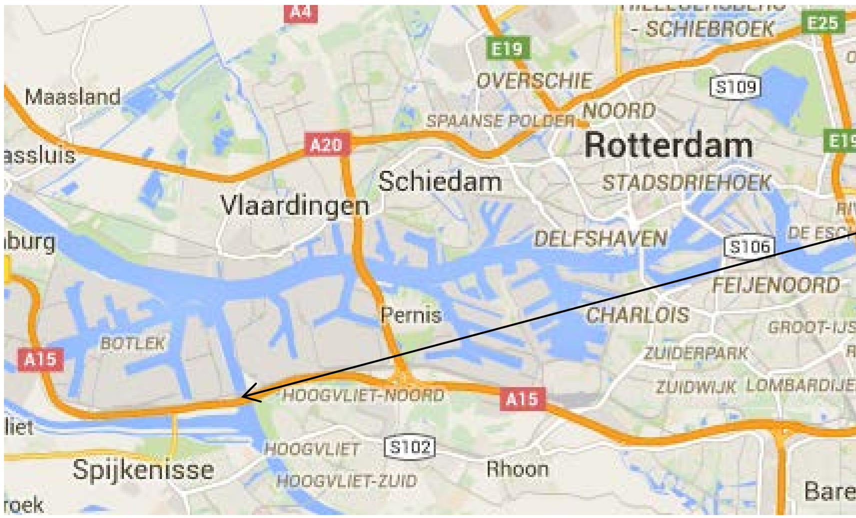
What Rijkswaterstaat wants: better traffic flow and shorter travel time. This means expanding the capacity of the A4 – A15 – A29

- 48 km road expansion
- renovation of 2 major motorway junctions
- Ca 70 new or adapted constructions
- Renovation of ca 50 viaducts

At the same time we take the opportunity to improve the quality of life of those living near these motorways:

- noise reducing asphalt
- noise barriers

Maasvlakte - Vaanplein



The current Botlek Bridge (combined railway and motorway bridge) will be replaced by a new lifting bridge across the Oude Maas, eliminating a major shipping bottleneck in the region. The new Botlek Bridge features two bridge passages – each around 90 metres wide – and will rise some 14 metres above water level. When completed, the new Botlek Bridge, which lifts to a maximum height of 45 metres, will be one of the largest moveable bridges in the world.

Special solutions to reduce traffic hinder

During exploitation this bridge must be opened within 200 seconds, and closed within 200 seconds

Botlek bridge. Double lifting bridge with 2 main spans of 90 meters. Combined railway and motorway bridge

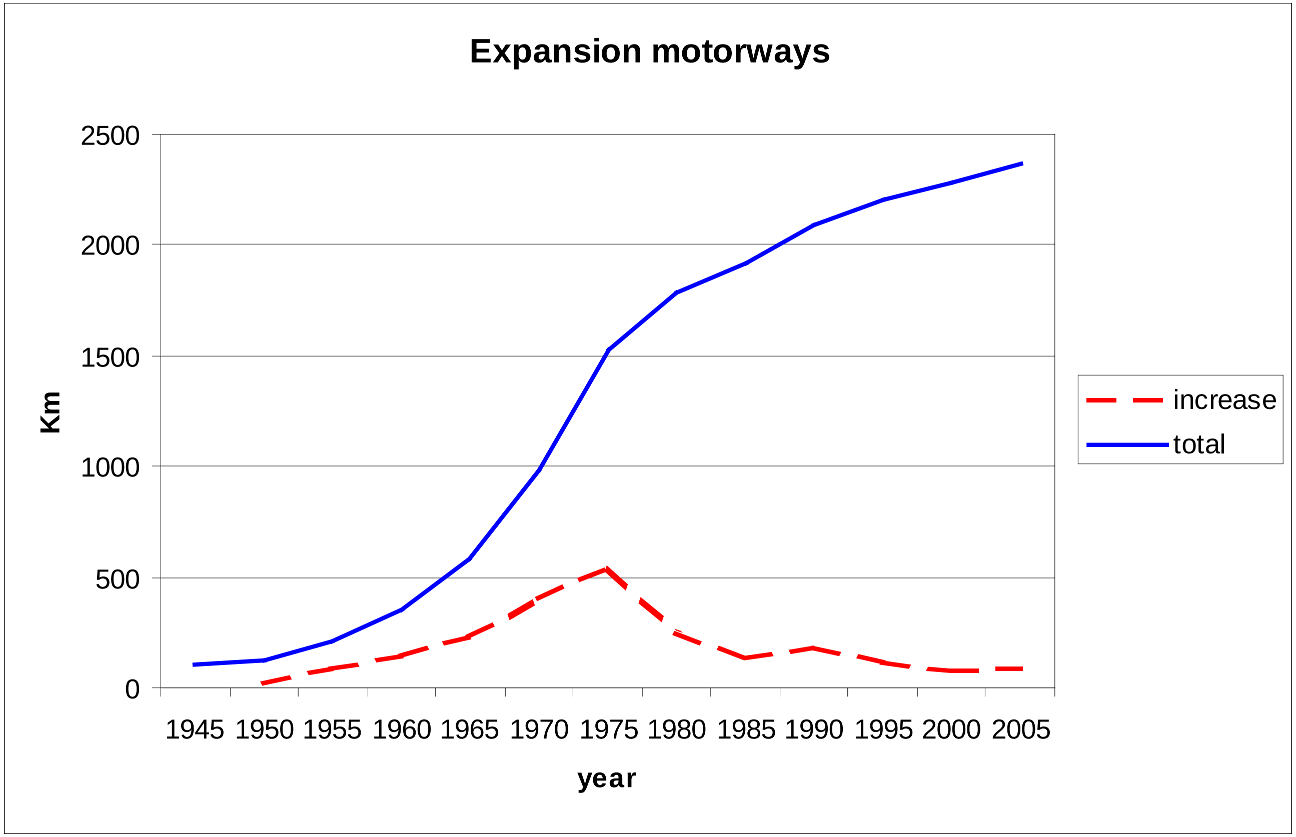
Prefab bridge decks

Latest developments

Prefab mid piers

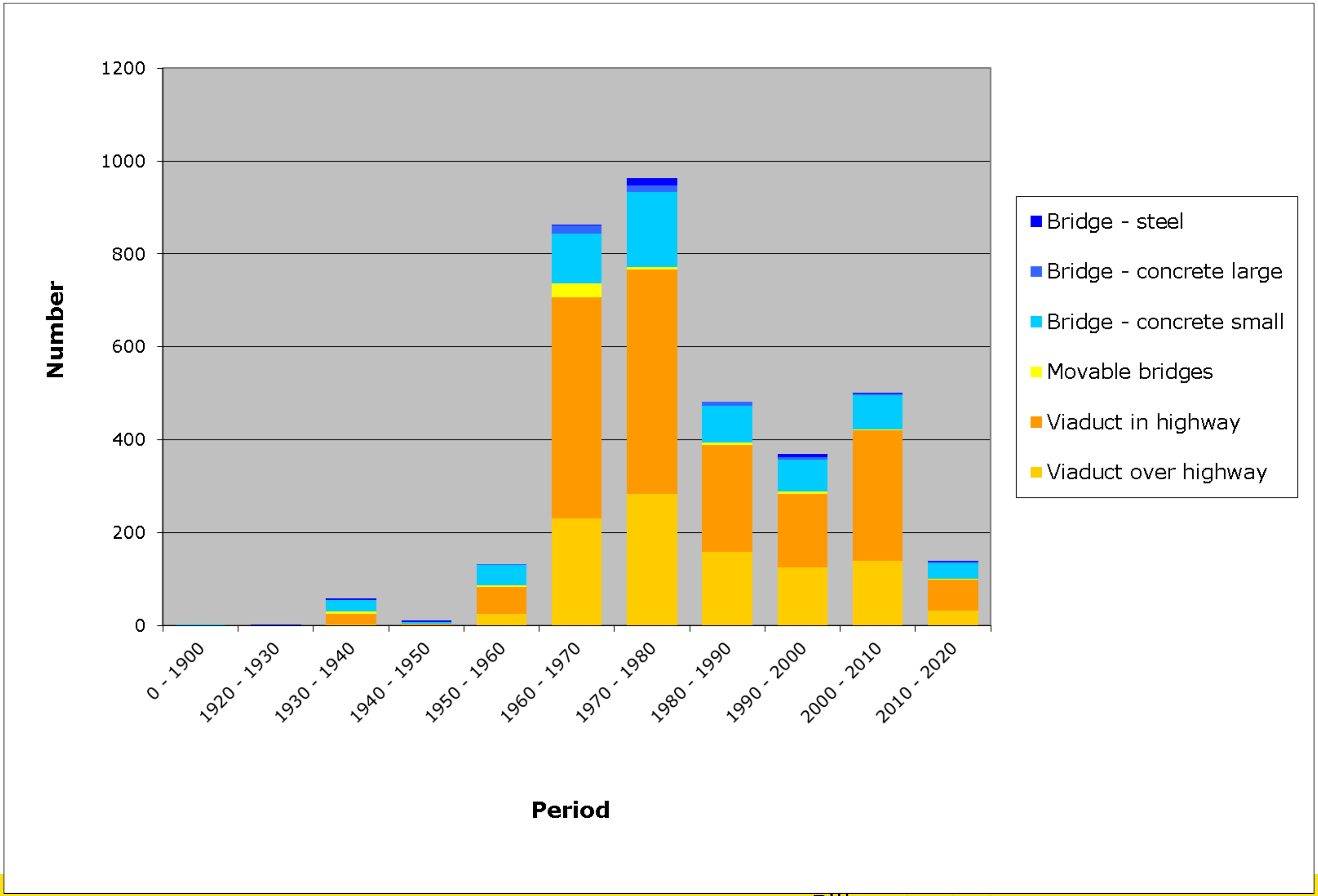
Management of an ageing bridge stock

Development motorways

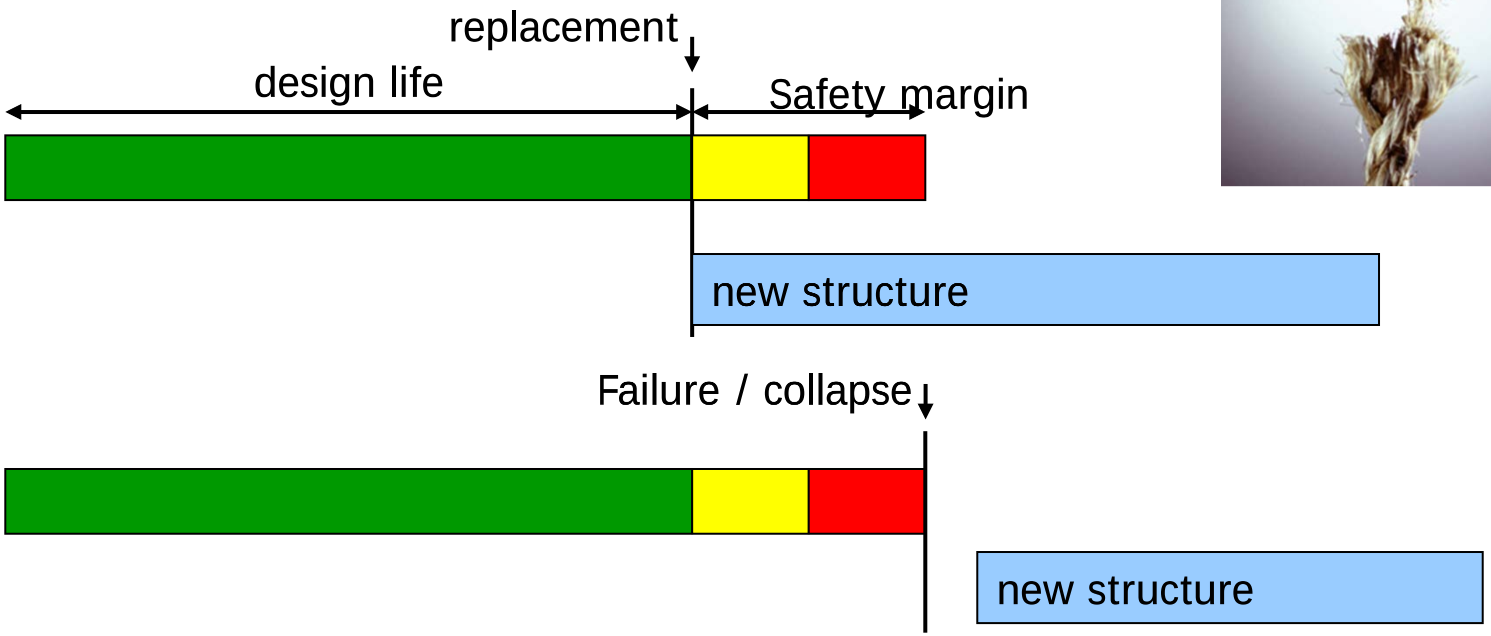


Number of vehicles 0.5 million (1960) -> 7 million (2007)

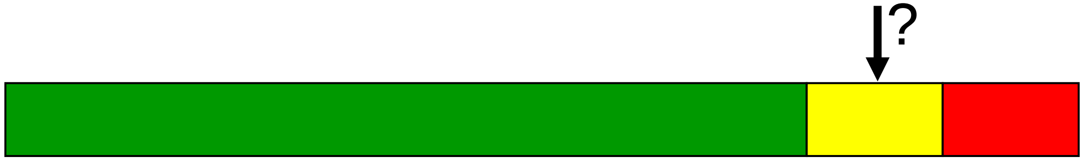
Age distribution bridges



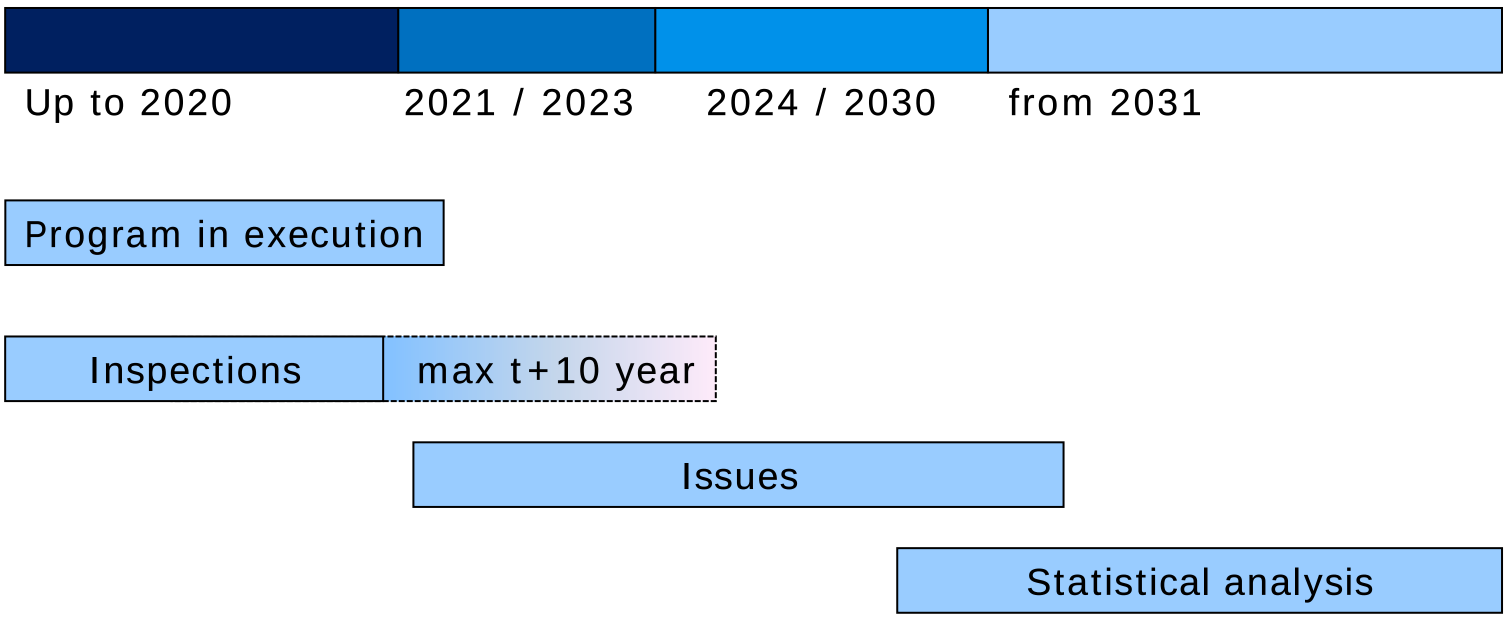
End of service life



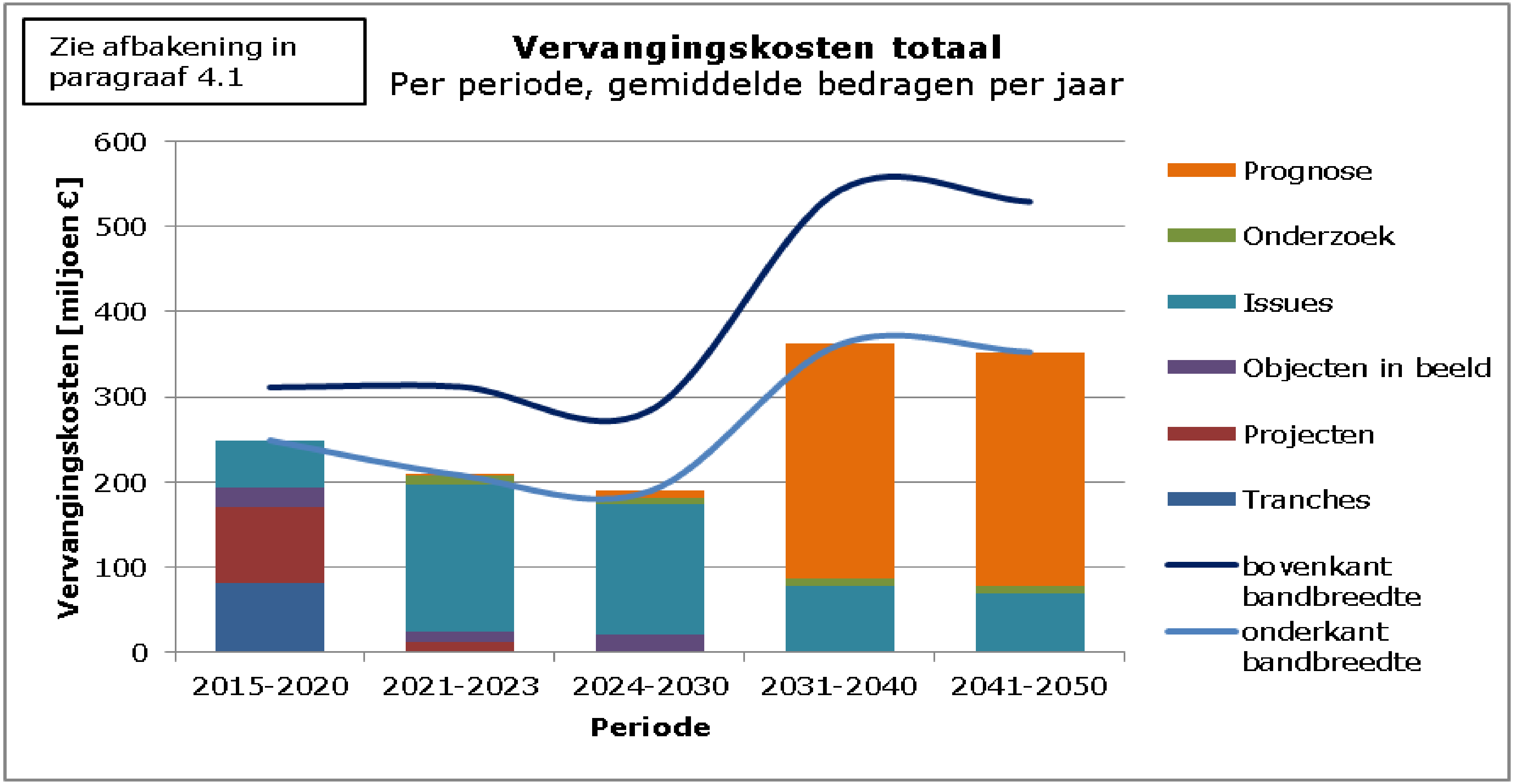
End of service life



Prognosis cost replacement & renewal



Prognosis cost replacement & renewal (3 networks)



Replacement & Renewal Program

Technical causes:

- Condition; worn out
- Outdated technology; regulations/ maintainability
- Economics; excessive cost of maintenance (LCC)

State budget ministry Infrastructure & Environment 2015, all three networks:

- Executional program € 650 million (t/m 2020)
- Reservation € 3,9 billion (2021 t/m 2028)
- Infrastructure investment program

Wilhelminalaan A15

completed

Developing monitoring

Present situation:

- Monitoring is used in case of actual risks for structural safety or durability
- Monitoring is used only when inspections or maintenance are no longer an option
- Few applications so far

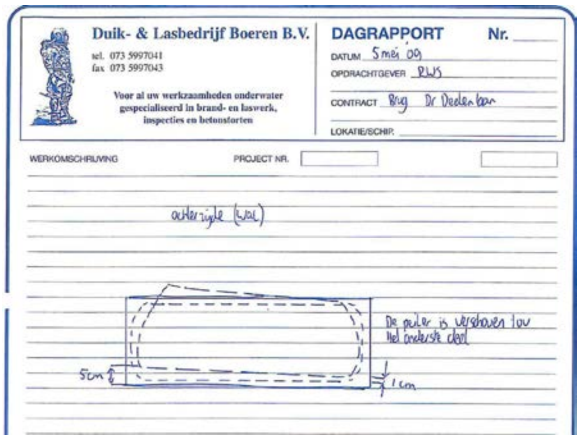
Integration in Bridge Management is needed to realize full potential:

- Interaction between monitoring and inspection
- Long term operation of monitoring systems

Data management:

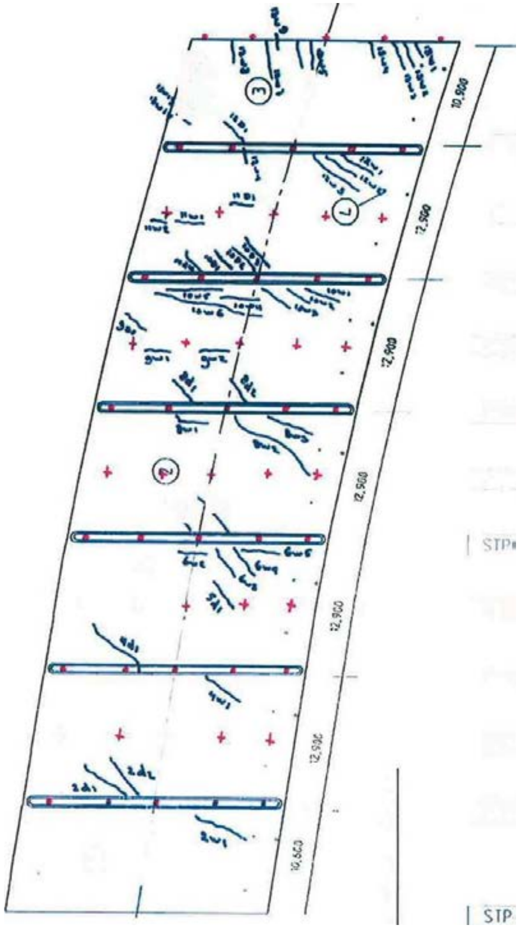
- Data needs interpretation to be useful for decision making

Traditional monitoring


Duik- & Lasbedrijf Boeren B.V.
tel. 073 5997041
fax 073 5997043
Voor al uw werkzaamheden onderwater gespecialiseerd in brand- en laswerk, inspecties en betonstorten

DAGRAPPORT Nr.
DATUM 5 mei 09
OPDRACHTGEVER RWS
CONTRACT
LOKATIE/SCHIP
WERKOMSCHRIJVING PROJECT NR.

De pijler is verschoven t.o.v. het onderste deel
5cm
1cm



Inspection based:

- Subjective results
- Labour intensive
- No continuous information flow

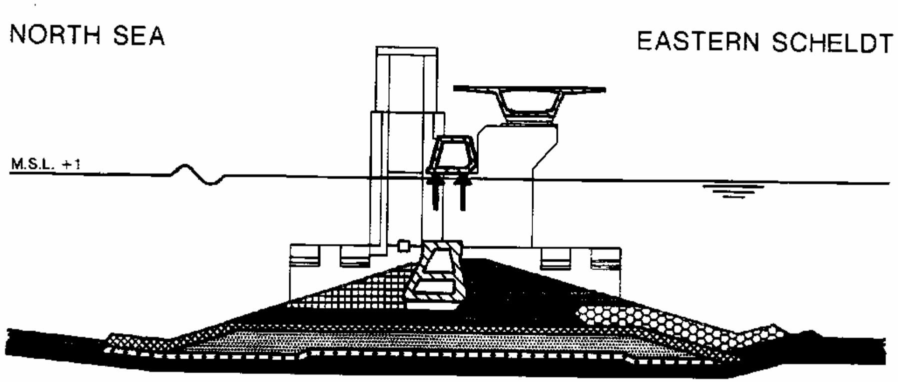
History of BHM in Netherlands (Rijkswaterstaat)

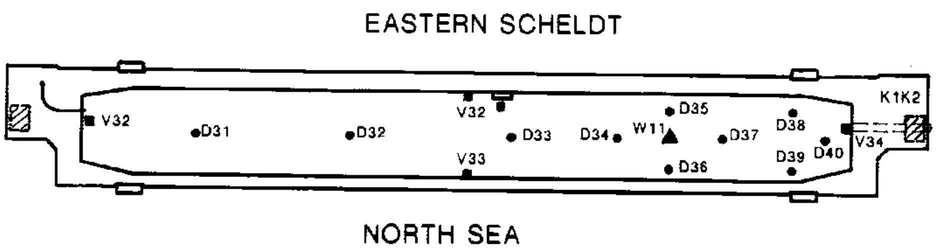
- Eastern Scheldt storm surge barrier; 1985-’95
- Traffic loads Moerdijk bridge; 1995
- WIM systems; 2001
- ASR affected bridges; 2000
- Brienenoord bridge, orthotrope deck; 2013
- Bridge Hagestein, main bearing system; 2014

Eastern Scheldt storm surge barrier

Evaluation design:

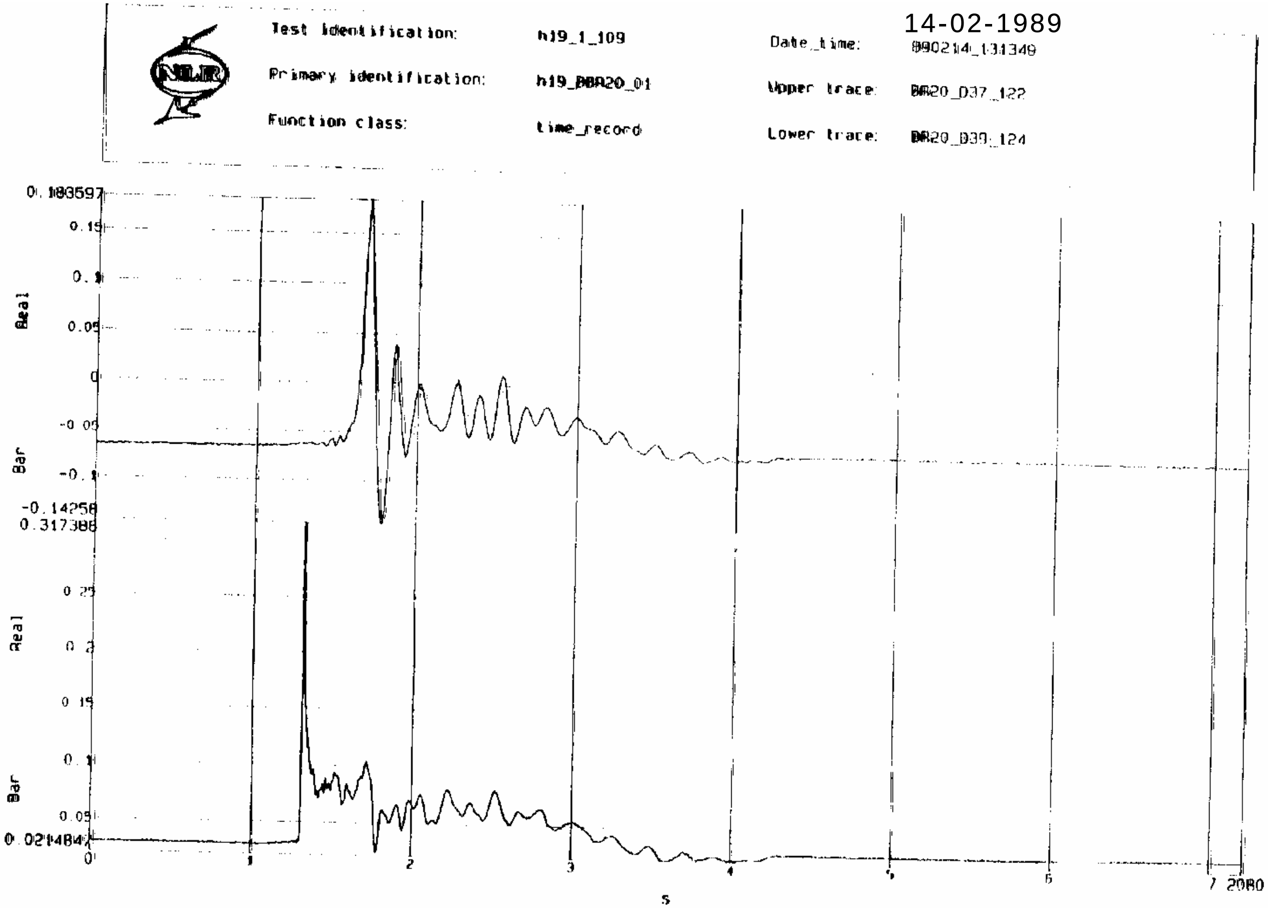
- Wave impacts
- Fatique steel gates
- Geotechnical aspects





● Pressure gauge.
▪ Accelerometer.
▨ Force gauge.
▲ Waterlevel gauge.

Results wave impacts upper beam



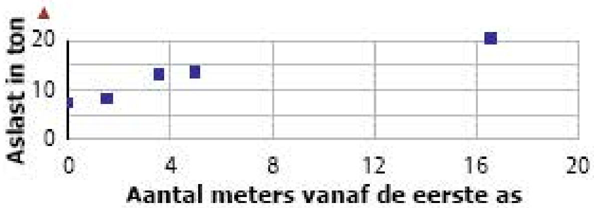
Bigger, heavier, larger numbers

Weigh in motion

Example extreme axle load

Datum:		7 december 2007
Tijd:		16:03:52
Voertuig nr:		57771400
Rijstrook:		5 R-L
Meetlocatie:		RW 004 1 HR L
Subcategorie:		0222
Snelheid (km/uur):		83

	asdruk (ton)		
	dynamisch	statisch	lengte (m)
totaal	102,0	0,0	19,70
	dynamisch	statisch	afstand (m)
as 1	7,4		0,00
as 2	8,3		1,51
as 3	13,3		2,06
as 4	13,6		1,40
as 5	20,5		11,58
as 6	38,9		1,62



Kenteken

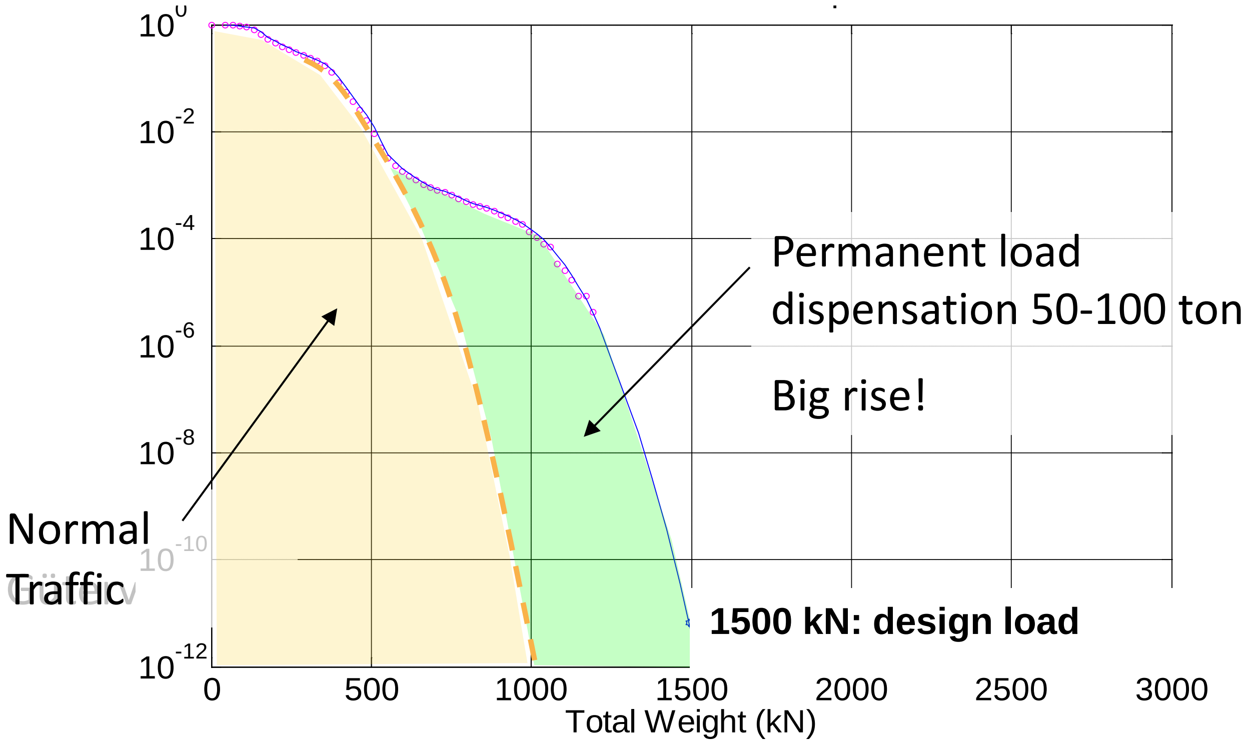
NB

Subcategorie

Effect on traffic loads

Transport prefab bridge elements

Results WIM measurements



ASR affected viaducts

Goal: extend service life:

- Risk of brittle collapse due to lack of shear reinforcement
- Shear strengthening is not an economical option
- Replacement of bridges is expensive and causes traffic congestion
- Large number of structures (18) with similar monitoring system
- Small ASR-expansions should be distinguished from temperature and moisture effects

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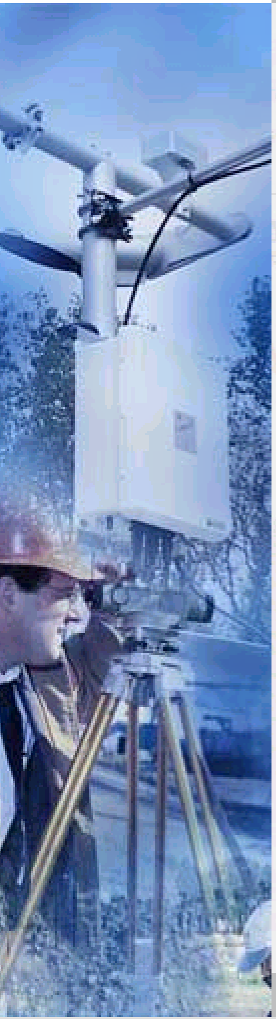
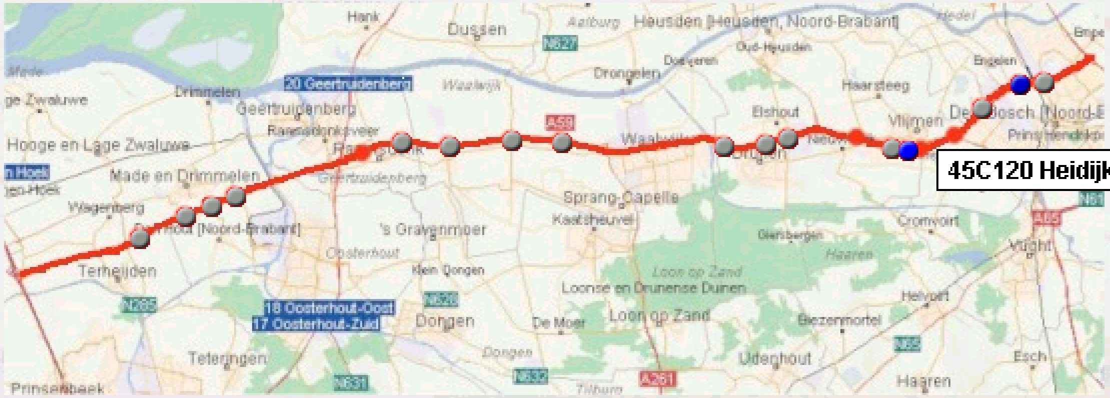
Ministerie van Verkeer en Waterstaat

Rijkswaterstaat

Monitoring Systeem A59



Overzicht



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5c-120 45C120 Heidijk Internet

Automated monitoring sytem

Total expansion of the bridge

Local expansion

Temperature

Moisture

Solar cell (primary) and battery (backup)

COMMUNICATION

DATA ACQUISITION SYSTEEM:
readout devises, multiplexers, data logger, GSM phone line

Bestand Bewerken Beeld Favorieten Extra Help

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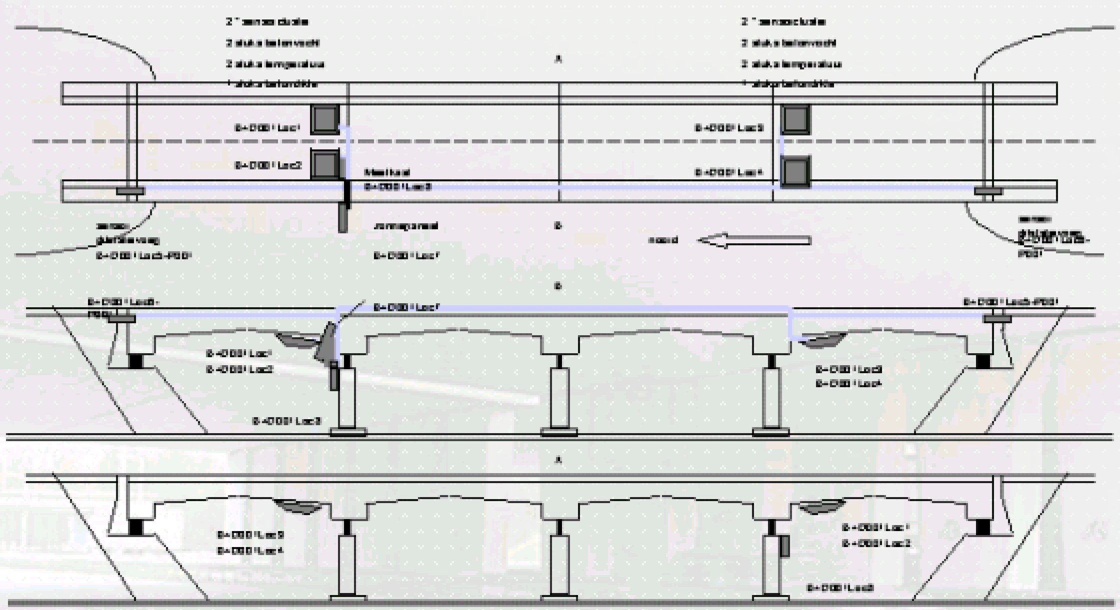
Selectie | Info | Foto's | Monitoring Systeem | Meetwaarden | Analyses | Tekeningen Archief

Viaduct Heidijk

Monitoring systeem



Sensoren

Locaties	Sensoren	Installatiediepte	Detail

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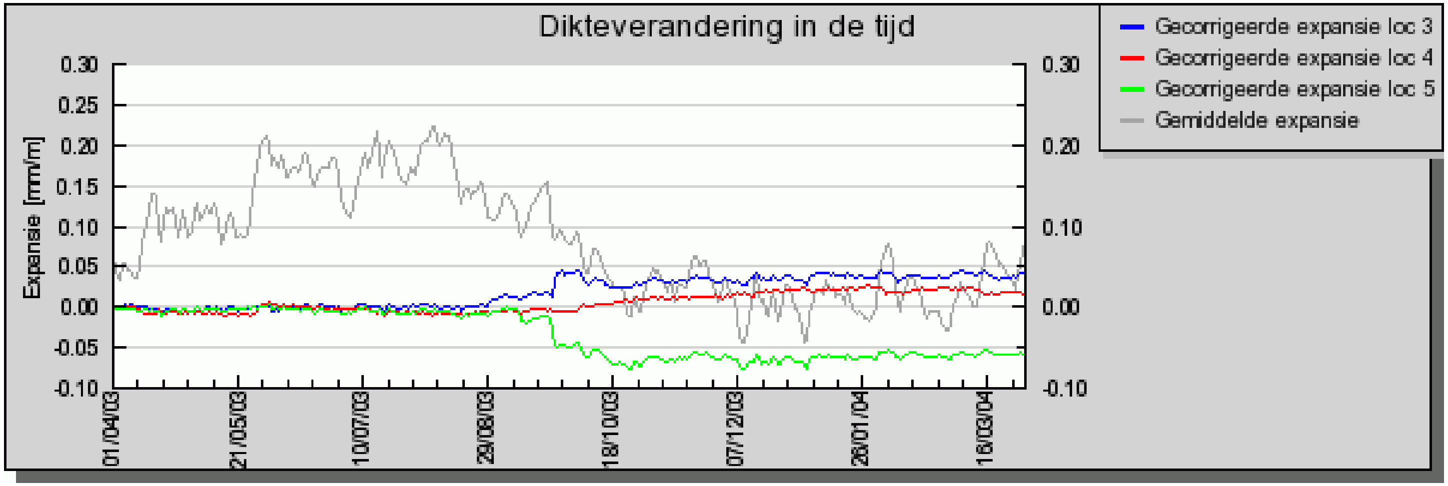
Internet

Standard analysis reports

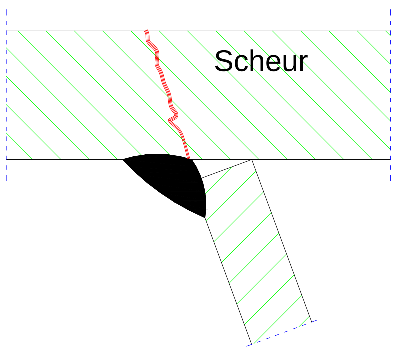


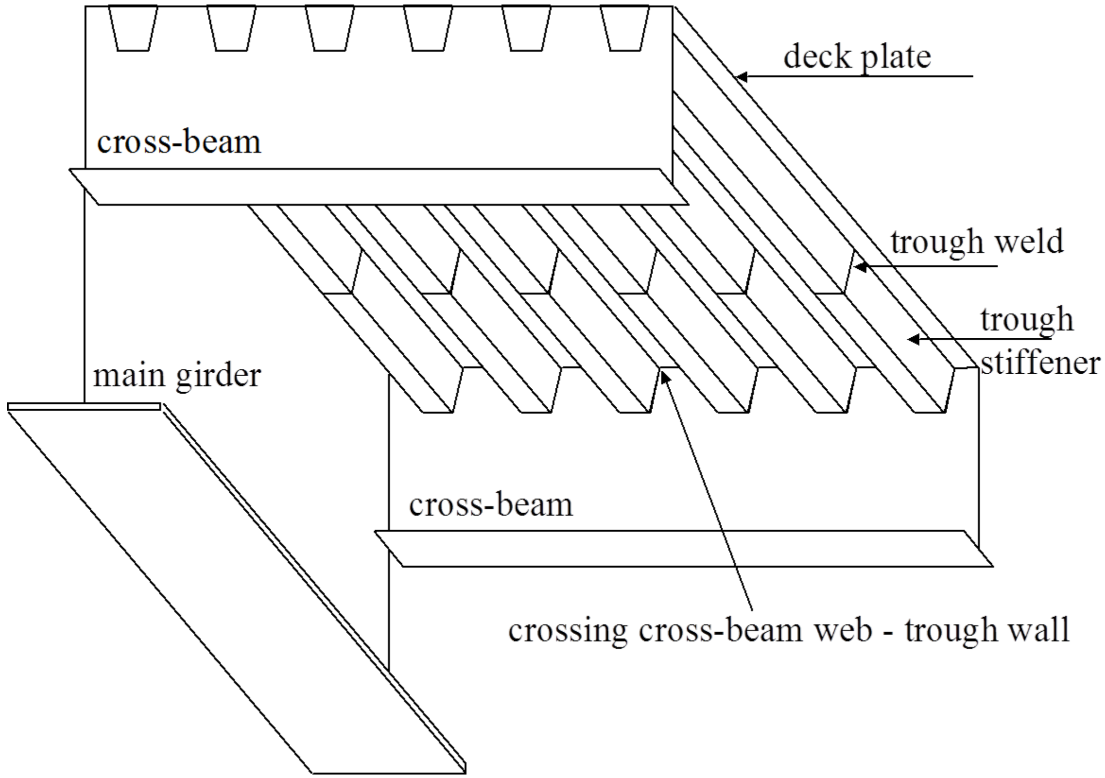
van Brienenoordbrug

- Fatique steel structure
- Monitoring integrated with prognostic model

Crack in steel deck of road traffic bridges

- Stress cycles cause initiation and growth of fatigue cracks
- Crack in deck; most dangerous, less visible, critical length 500 mm,

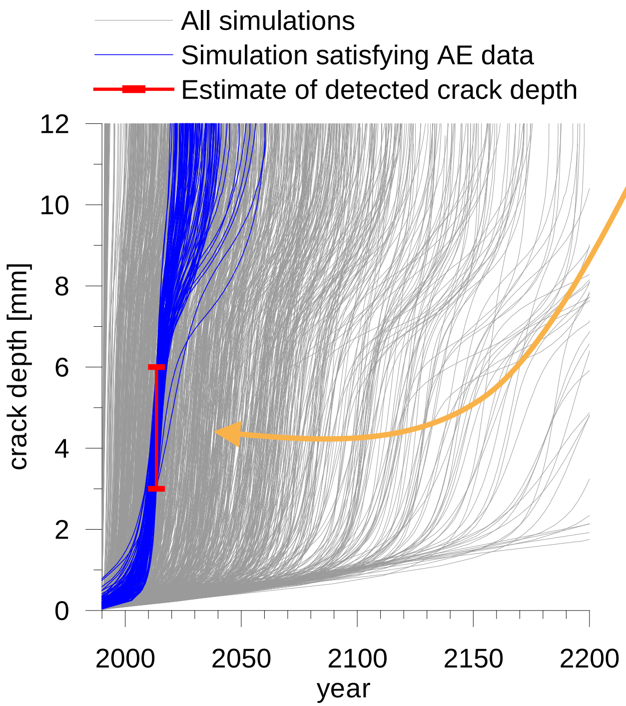




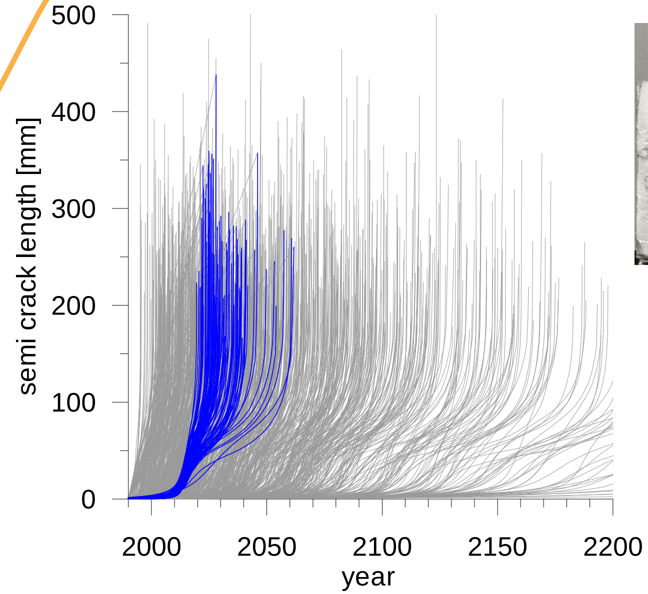
Development van Brienenoordbrug

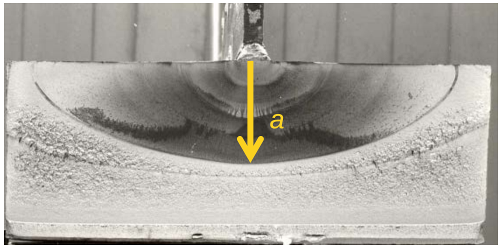
- Monitoring system for more reliable service life prediction and inspection interval
  - 2010 – 2012 Lab en desktop experiment
  - 2012 – 2013 Bread board 4 x 2 meter steel structure
  - 2013 – 2014 Demonstrator van Brienenoord Brug
  - 2015 – 2018 Application of full prototype

Fatigue crack growth model (LEFM)

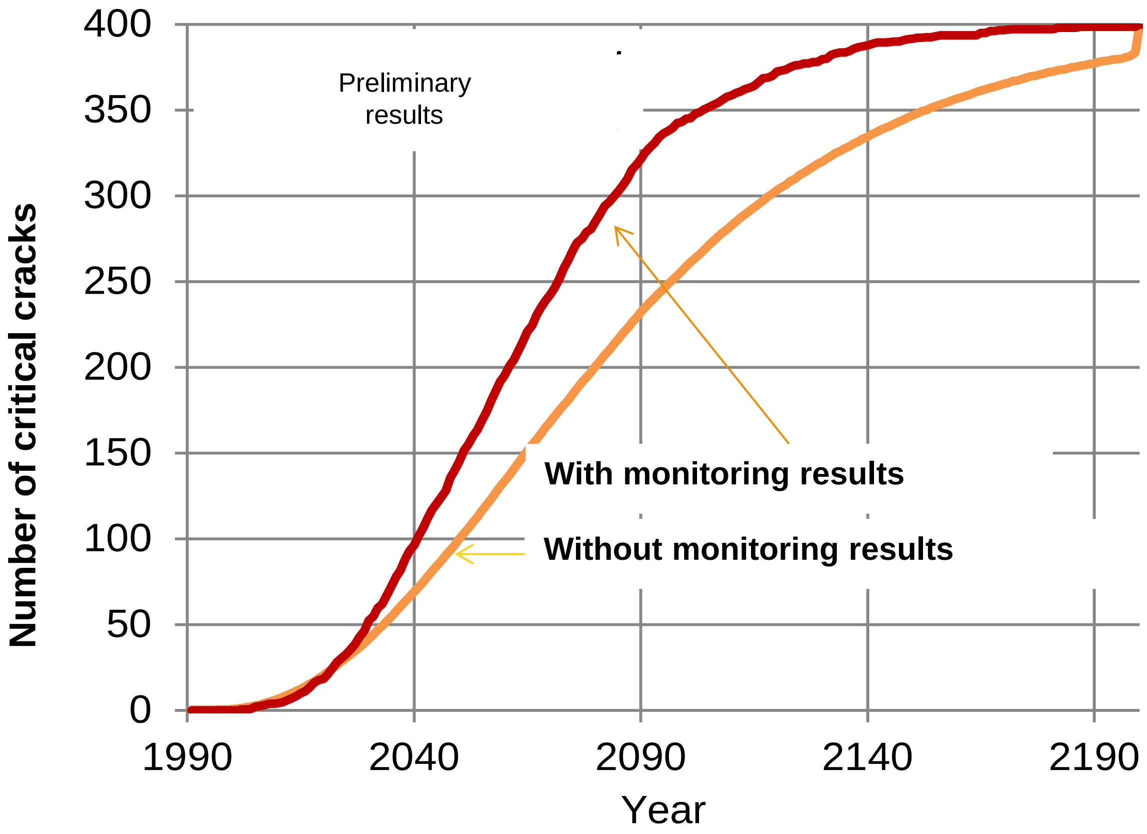


Updating with crack size

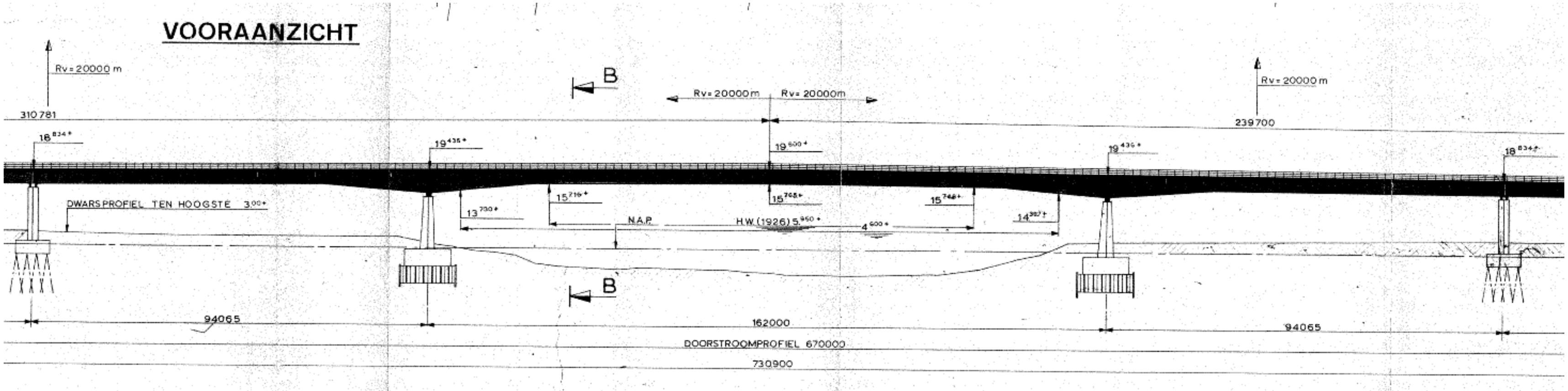


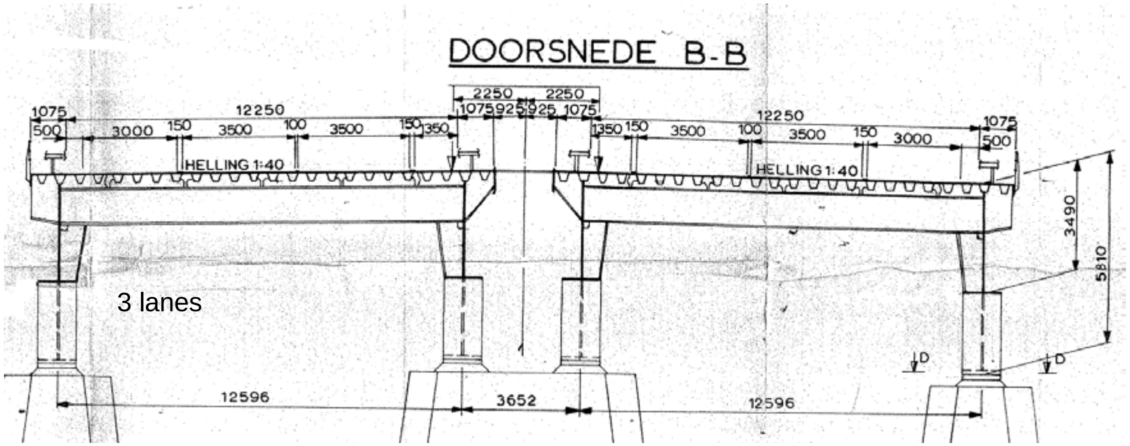


Service life prediction - number of critical cracks -

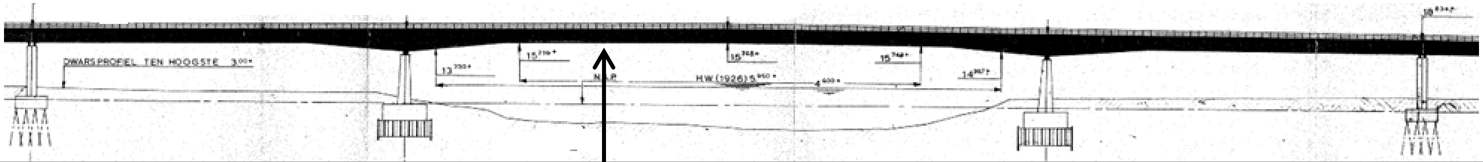


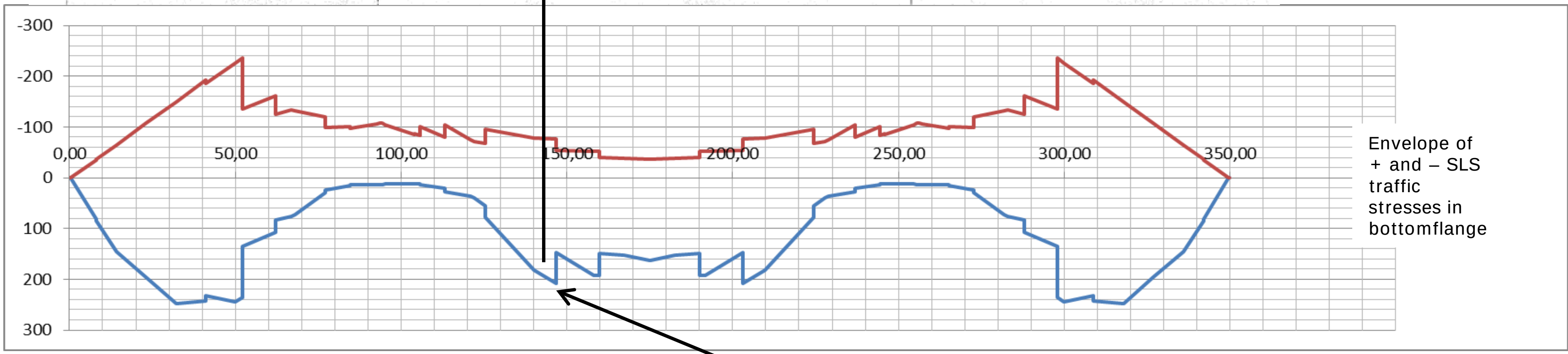
Hagestein bridge - static strength:





SLS traffic calculation versus measurement



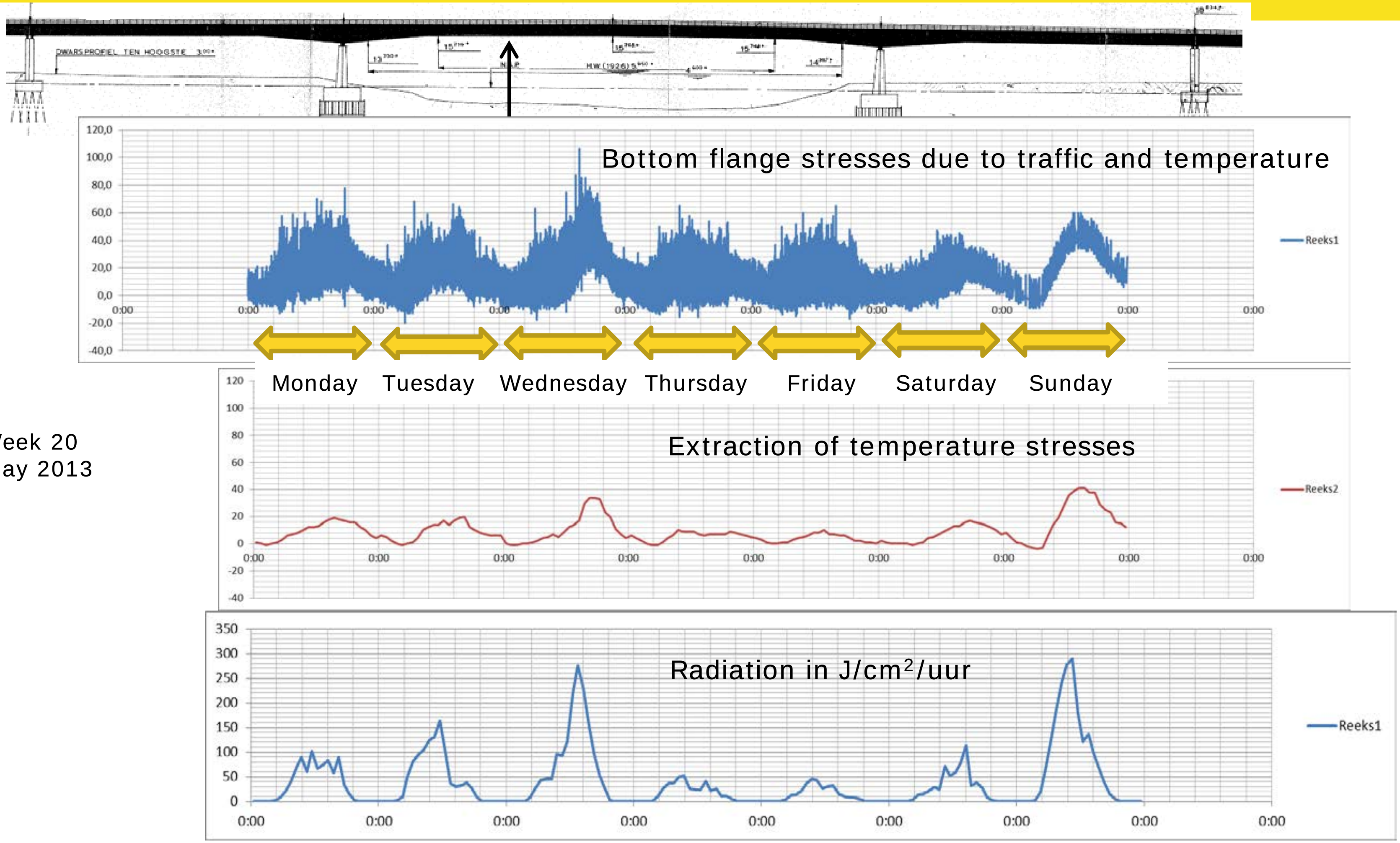


Main span max traffic stresses in bottom flange:
+ 207 N/mm2 (SLS)*1,25= **259** N/mm2 (ULS)

Osmos optical 2 m long
extension measuring device
2 Hz measuring for 20 weeks

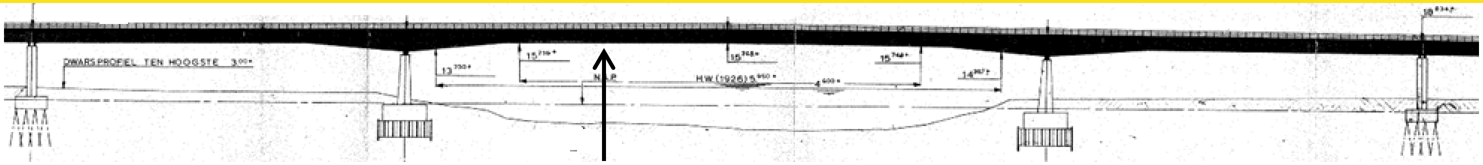
SLS traffic

calculation versus measurement

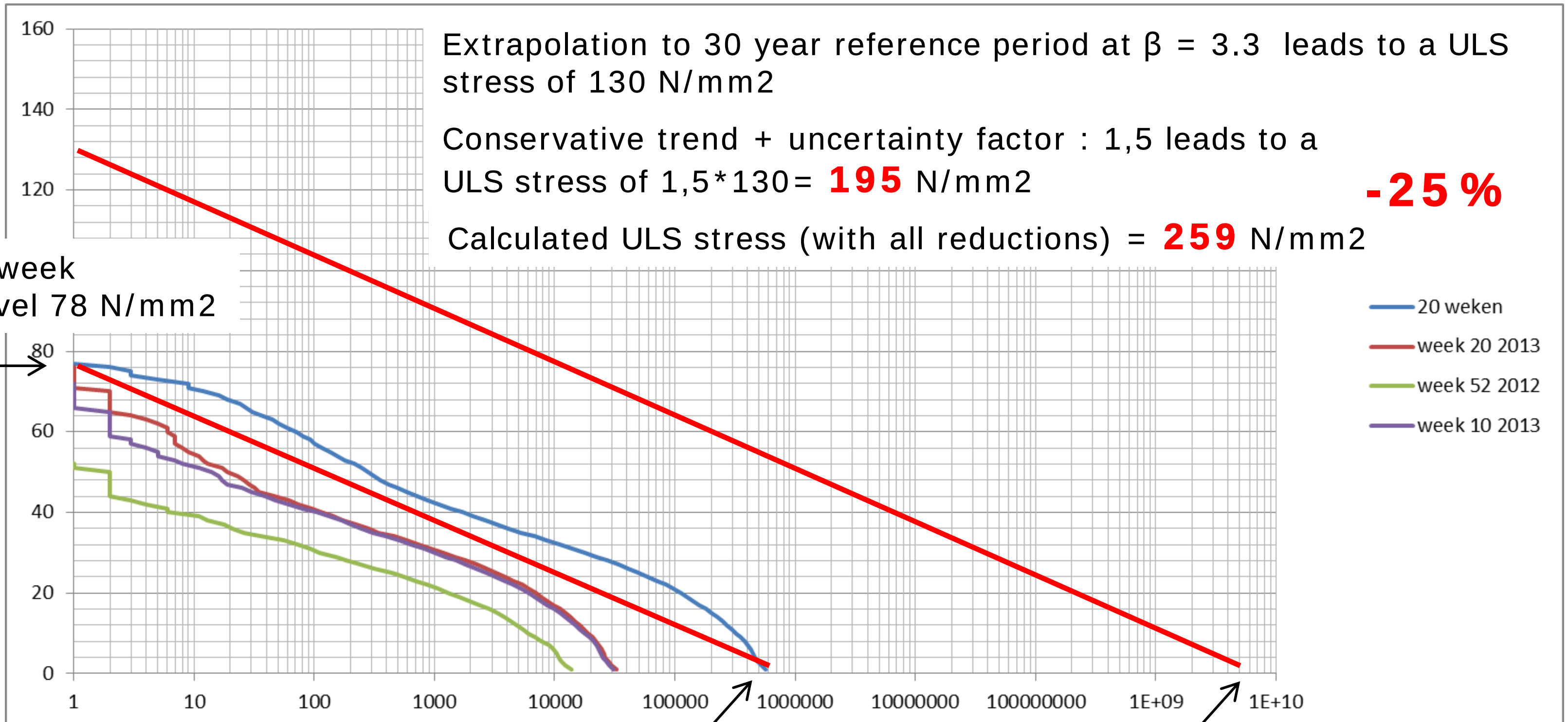


Week 20
may 2013

SLS traffic calculation versus measurement



SLS 20 week stresslevel 78 N/mm2



600.000 pieks >0

ULS β = 3.3 : 1/3000 year

Cumulative excendence line main span max SLS tension stress in bottom flange

Satellite measurements: INSAR

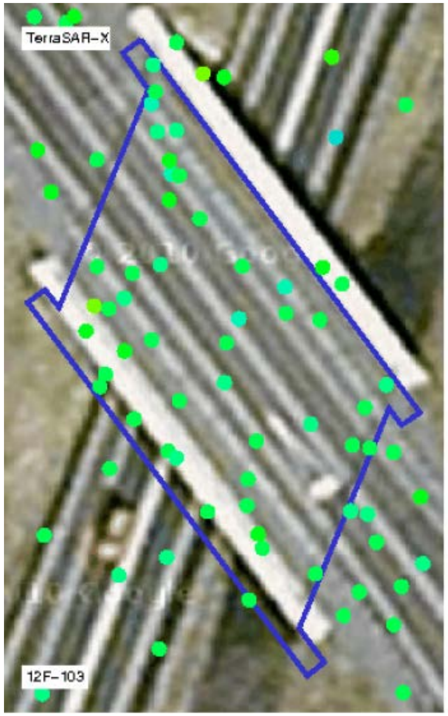
INSAR alternative for Z plane measurements?

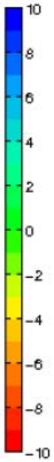
- INterferometric Synthetic Aperture Radar
- No physic measurement points on structure

INSAR potential:

- No traffic disturbance
- Historical data of structures where no traditional data is available
- Lower costs?

INSAR results





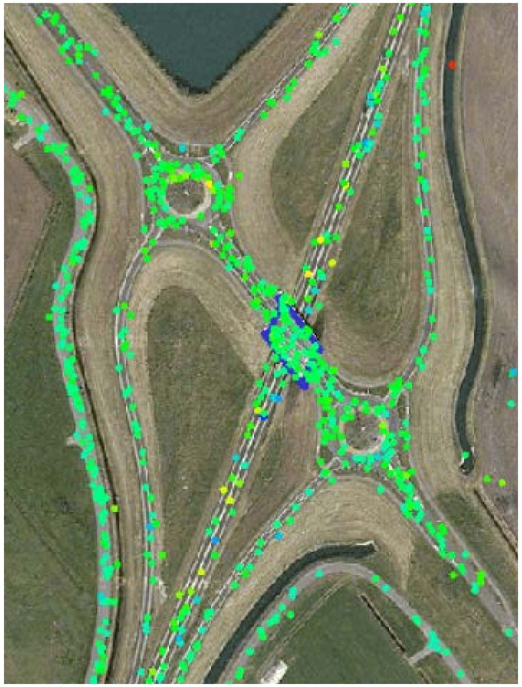
Findings:

1-2 mm/per year

Sudden vertical deformation around February / March 2013

Low resolution images provide insufficient data to follow deformation in Z plane

Analysis of high resolution images currently taking place



Conclusions: from network level

- Total system approach
- Multi level – load <–> strength
  - Functional demands – traffic volumes, composition, reliability, safety
  - Technical demands – traffic loads
  - Local effects – stress – strain – vibration
- Development over time

Monitoring will not function in isolation!

Conclusions: from object level

Treat object as “individuals” who form a “society”

- Applications must be customized to objects
- Goals can be different:
  - Findings one object can be applied to a group objects
  - Aimed at behavior critical element individual object
  - Result necessary to tune operational parameters, example current cathodic protection

- Attention: snapshot aspect; time for action needed; safe threshold value, extrapolation observations, integrate prognostic model

Conclusions: organizational level

- Fits in organizational processes:
  - Knowledge
  - Responsibilities
- Specific attention long term programs:
  - Able to survive reorganizations and shift of policies and priorities
- Costs:
  - All costs over lifecycle covered; including maintenance, and replacement

Discussion

Meetkundige Dienst Afdeling Grafische Technieken
Bouwdienst Rijkswaterstaat
16-09-1999 knooppunt Ridderkerk A5/A16