Predicting the impact of climate change on pipe failure in drinking water distribution systems.

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BTO

Knowledge for Climate

Introduction

Drinking water distribution network
~ 120 000 km pipe under the ground in the Netherlands
composed of different pipe materials

Occurrence of pipe failure
~ 3000 – 4000 pipe failures per year in the Netherlands

Study on long-term predictions of pipe failure

Introduction

Method is developed to estimate *future* (long-term) pipe failure frequencies

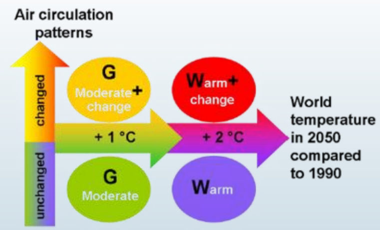
Accounting for
- Effect of climate change
- Evolution of the network (replacement of pipes and ageing)

Using statistical analysis on failure registrations

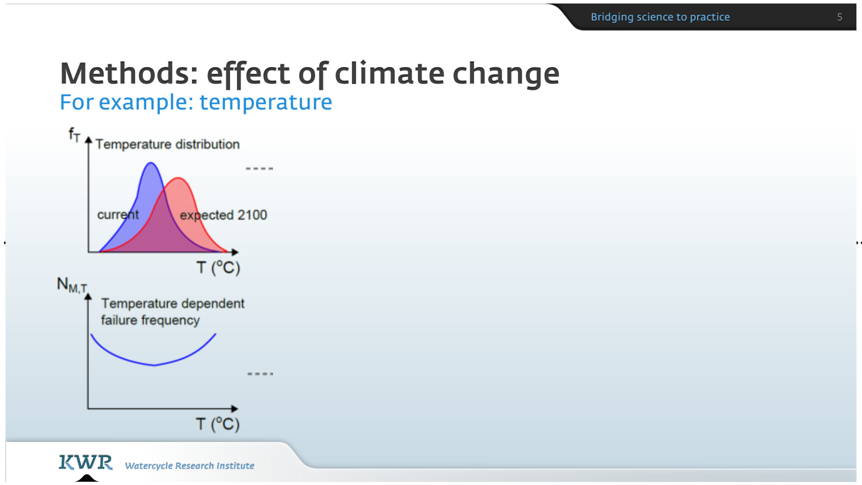
Methods: effect of climate change

Scenarios developed by the Royal Dutch Meteorological Institute (KNMI, 2006)

Scenario for 2050:



Scenario for 2100: similar but temperature rise is twice as high.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Methods: effect of climate change
For example: temperature
f_T
Temperature distribution
current
expected 2100
T (°C)
$N_{M,T}$
Temperature dependent
failure frequency
T (°C)
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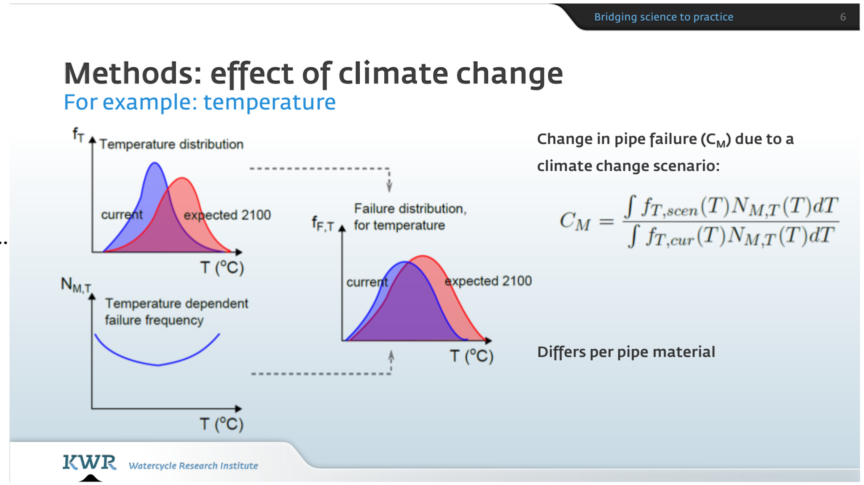
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Methods: effect of climate change
For example: temperature
f_T
Temperature distribution
current
expected 2100
T (°C)
$N_{M,T}$
Temperature dependent
failure frequency
T (°C)
$f_{F,T}$
Failure distribution,
for temperature
current
expected 2100
T (°C)
Change in pipe failure (C_M) due to a
climate change scenario:
$C_M = \frac{\int f_{T,scen}(T) N_{M,T}(T) dT}{\int f_{T,cur}(T) N_{M,T}(T) dT}$
Differs per pipe material
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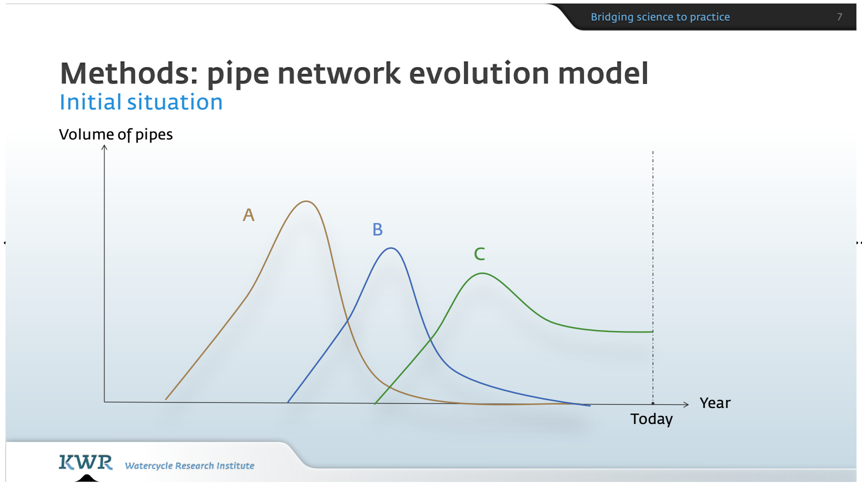
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Methods: pipe network evolution model
Initial situation
Volume of pipes
A
B
C
Year
Today
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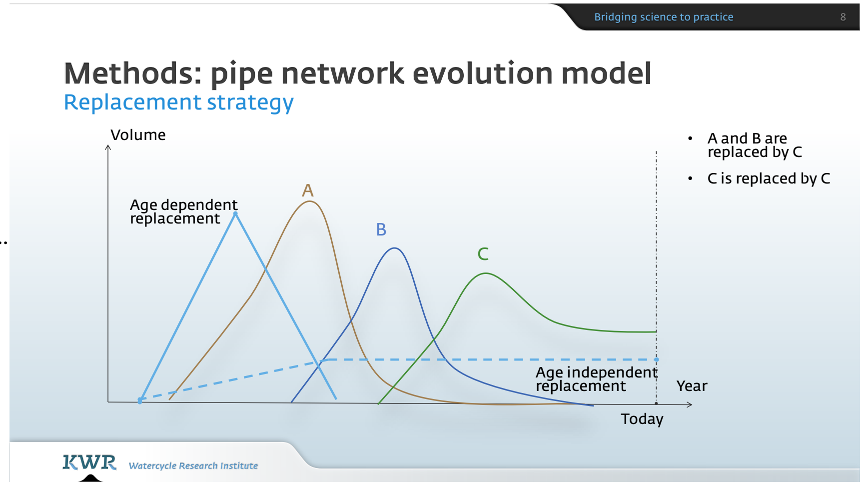
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Methods: pipe network evolution model
Replacement strategy
Volume
• A and B are replaced by C
• C is replaced by C
Age dependent replacement
A
B
C
Age independent replacement
Year
Today
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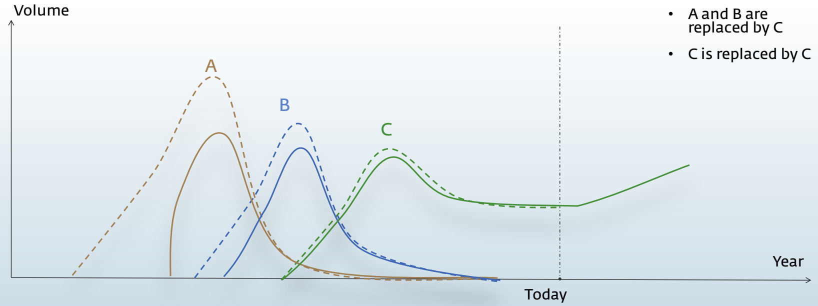
Methods: pipe network evolution model

Evolution of pipe materials



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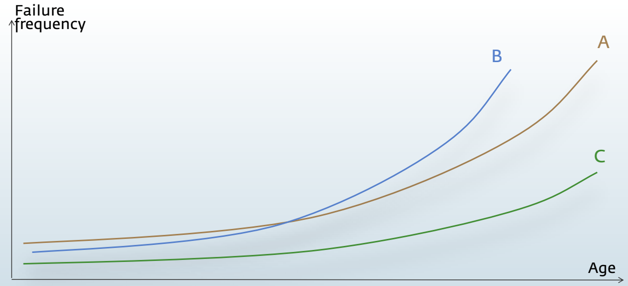
Methods: pipe network evolution model

Ageing of pipe materials



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Methods: Failure frequency calculation

Combining climate change and pipe evolution

The volumes (l_M) over the years are combined with the ageing curve ($N_m(t)$) to determine the failure frequency ($N_{m,f}$) for a specific pipe material (A, B or C):

$$N_{M,f} = \frac{\int N_M(t) l_M(t) dt}{\int l_M(t) dt}$$

Combining evolution of network and climate change:

Pipe failure frequency (P_f) in complete network

$$P_f = \frac{\sum_M N_{M,f} L_M \boxed{C_M}}{\sum_M L_M}$$

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Methods

Settings of model

Pipe network evolution model:

- Three pipe materials: AC, GCI (grey cast iron) and PVC
- AC and GCI are replaced by PVC
- Age dependent replacement according to triangular distribution (starting at 80 years, peak at 100 years and ends at 140 years).
- Age independent replacement by 0.5% of the volume per year
- Total length of the complete network remains the same

Climate effect model:

- Temperature was determined to be most influencing climate variable

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Scenario study
The Netherlands

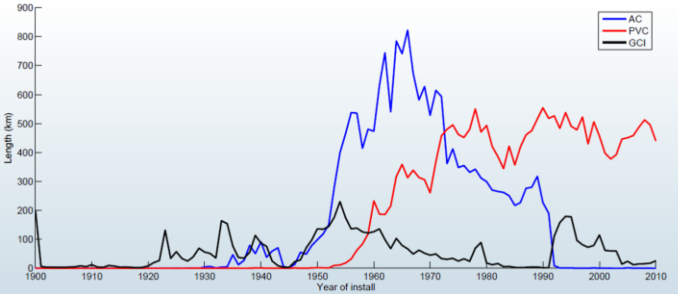
Data from failure registration in the Netherlands (USTORE, about half of NL)

Material	Length (1000 km)	# failures	Freq (#/km/yr)	Age (yr)
AC	18,1	5398	0,0659	50
PVC	22.6	1311	0,0132	30
GCI	6.2	886	0,0315	63

Results

1. Evolution of drinking water distribution network
2. Effect of climate change
3. Prediction of pipe failure for future networks

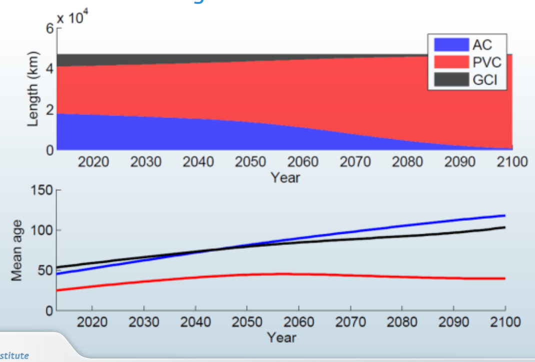
Evolution of water distribution network
Existing situation (2013)



Evolution of water distribution network

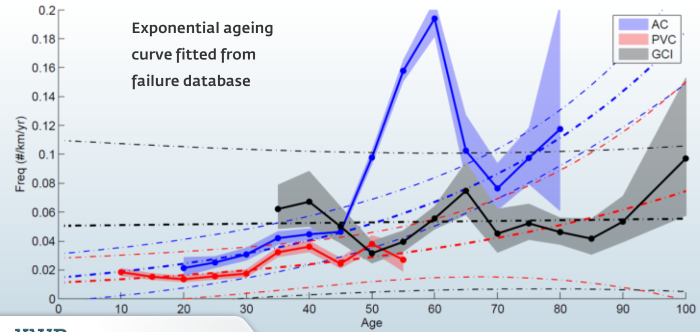
Expected composition and mean age

Long-term predictions



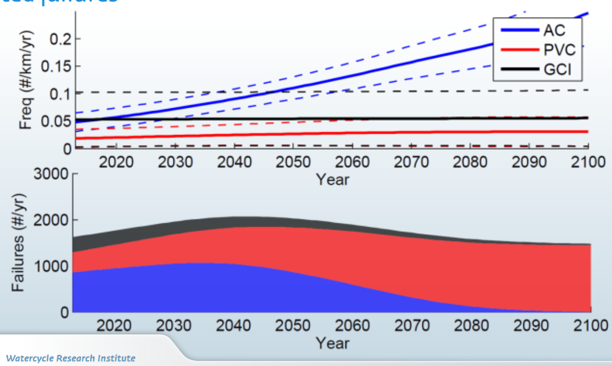
Evolution of water distribution network

Ageing of the pipes



Evolution of water distribution network

Expected failures



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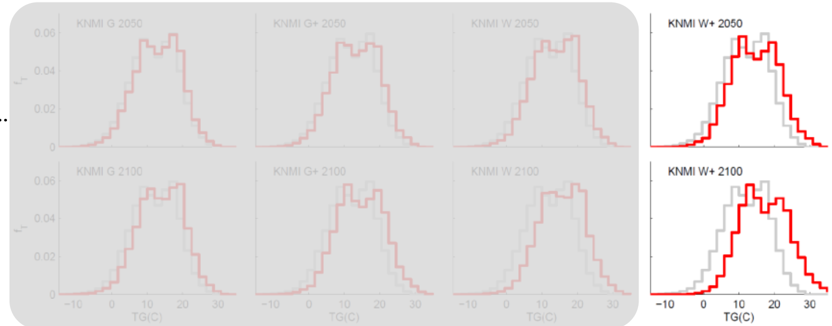
Effect of climate change

Scenario for temperature distribution in the Netherlands (De Bilt)



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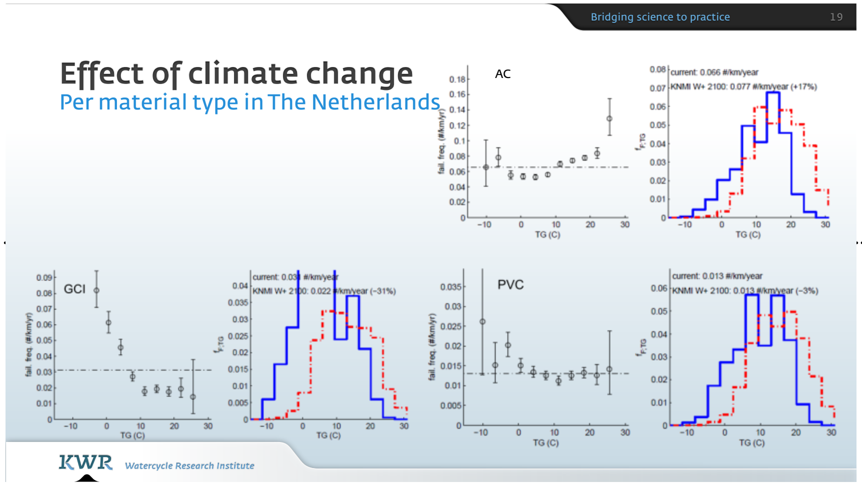
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Effect of climate change
Per material type in The Netherlands
AC
current: 0.066 #/km/year
KNMI W+ 2100: 0.077 #/km/year (+17%)
GCI
current: 0.032 #/km/year
KNMI W+ 2100: 0.022 #/km/year (-31%)
PVC
current: 0.013 #/km/year
KNMI W+ 2100: 0.013 #/km/year (-3%)
fail. freq. (#/km/yr)
TG (C)
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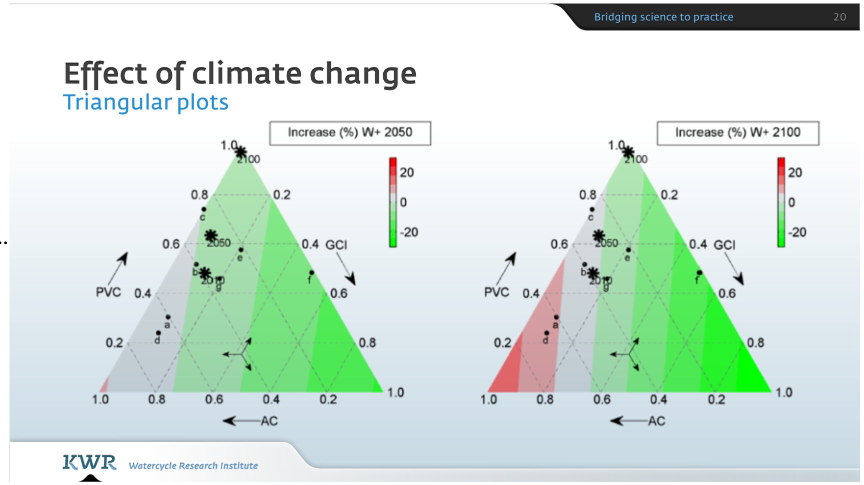
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Effect of climate change
Triangular plots
Increase (%) W+ 2050
Increase (%) W+ 2100
20
0
-20
GCI
PVC
AC
2050
2100
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Climate change and evolution of network

Prediction of failure

Scenario	Freq (#/km/yr)	Dif with current climate
current 2013	0.0343 (+/- 0.0121)	0.0 %
current 2050	0.0571 (+/- 0.0157)	0.0 %
current 2100	0.0335 (+/- 0.0251)	0.0 %
W+ 2050	0.0582 (+/- 0.0155)	1.9 %
W+ 2100	0.0333 (+/- 0.0245)	-0.4 %

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Discussion

Weather parameters

- different parameters (other than temperature) may be important at different locations
- relation between temperature and failure may be age dependent

Uncertainty in ageing curve predictions

Different replacement strategies can be assessed

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Conclusions

Methodology to estimate occurrences of pipe failure in the future:

- Climate change scenario
- Pipe network evolution
- Applicable for any region where failure registration and climate change scenarios are available

Results for a case study in the Netherlands:

- Direct of effect climate change is small
- Largest variations in pipe failure are related to ageing of the pipes

Use of model for pipe replacement (asset management) strategies and climate change adaptation.

Questions?

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