

Modes of Failure of South African Local Government in the Water Services Sector
Paper submitted to the 2015 International System Dynamics Conference
Submission #1115

Supplementary material 3: Sensitivity Analysis

Introduction:

Sensitivity analysis is a way of assessing which of the uncertain parameters lead to major changes in the model results. As discussed in sub-section 5.4 of the paper on the ‘Modes of Failure of South African Local Government in the Water Services Sector’, a sensitivity analysis was one of the types of model validation performed in this study. The sensitivity analysis was performed using the built-in Monte Carlo simulation function in Vensim DSS, Version 6.3 for Macintosh. A total of seven parameters were varied in this analysis over a wide range of uncertainty (as summarised in Table 3.1 below and individually reported upon in the remainder of this document). For comparative purposes, the stock variable of ‘Infrastructure capacity’ was used as a Key Performance Indicator (KPI) for all simulations, with the simulation results of additional variables saved according to what was being tested and why. Sensitivities are shown here using graphs of ‘Confidence Bounds’ specifying four confidence intervals.

Table 3.1: Summary of the sensitivity analysis runs performed for the ‘Modes of Failure’ system dynamics model.

	Testing variable(s)	Run name	No. of runs	Noise seed	Multi or univariate	Significant changes in infrastructure capacity?
1	“annual municipal financial bailout”	SensAna1	200	1234	Univariate	No
2	“percentage annual revenue ringfenced per year”	SensAna2	200	1234	Univariate	No
3	“average loss percentage”	SensAna3	200	1234	Univariate	No
4	“reference unit productivity”	SensAna4	200	1234	Univariate	No
5	“hiring rate” + “reference unit productivity”	SensAna5	200	1234	Multivariate	No
6	“average annual water use per connected household” + “average loss percentage”	SensAna6	200	1234	Multivariate	No
7	“average refurbishment and construction time”	SensAna7	200	1234	Univariate	No

1: Univariate analysis – annual municipal financial bailout

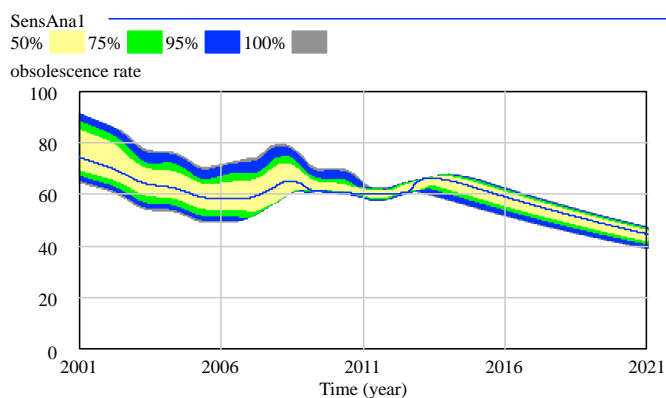
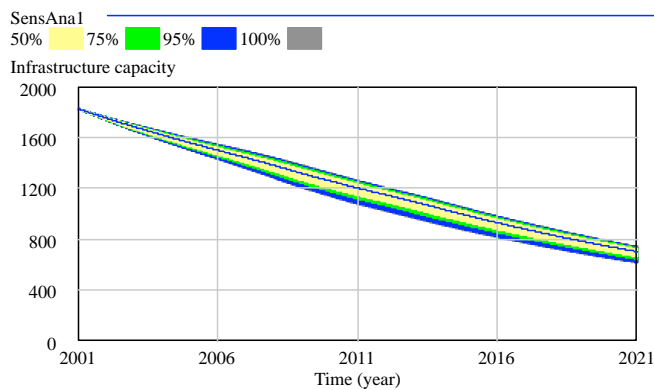
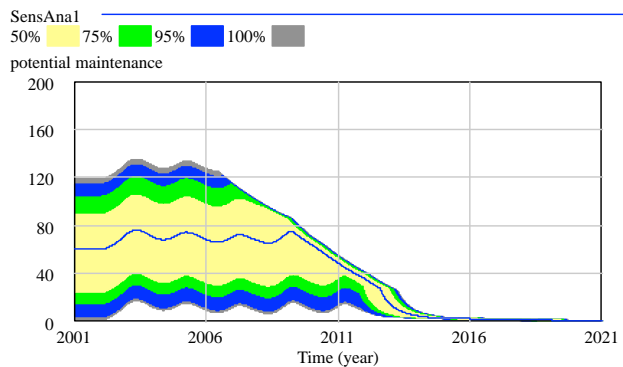
Run name: *SensAnal*

Variables saved as KPIs: Infrastructure capacity; potential maintenance;

	Base case values	Ranges of Uncertainty
1.	annual municipal financial bailout = R150000 /year	Uniform (0,300000)

Motivation:

The “annual municipal financial bailout” parameter is an estimation. Over periods of financial crises in the municipality, it is conceivable that bankruptcy would prevent any form of bailout occurring. Hence a range of uncertainty is tested here between the values of R0 per year through to R300000 per year.



2: Univariate analysis – Percentage annual revenue ringfenced per year

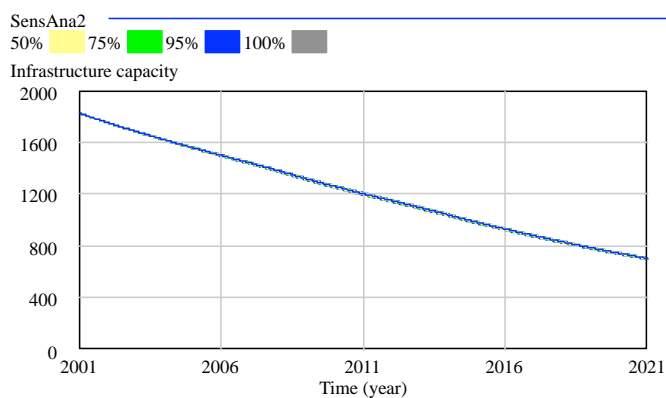
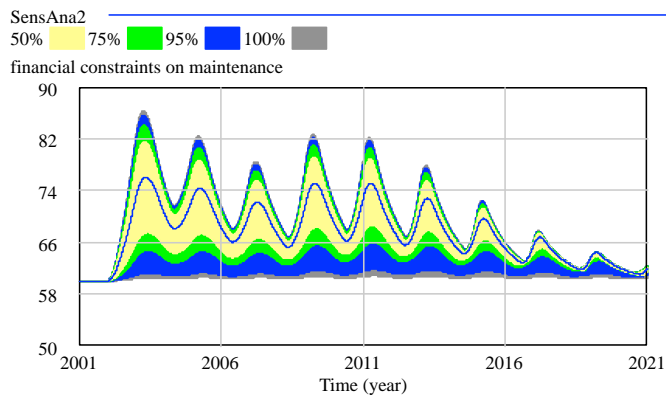
Run name: *SensAna2*

Variables saved as KPIs: Infrastructure capacity; potential maintenance; obsolescence rate; financial constraints on maintenance;

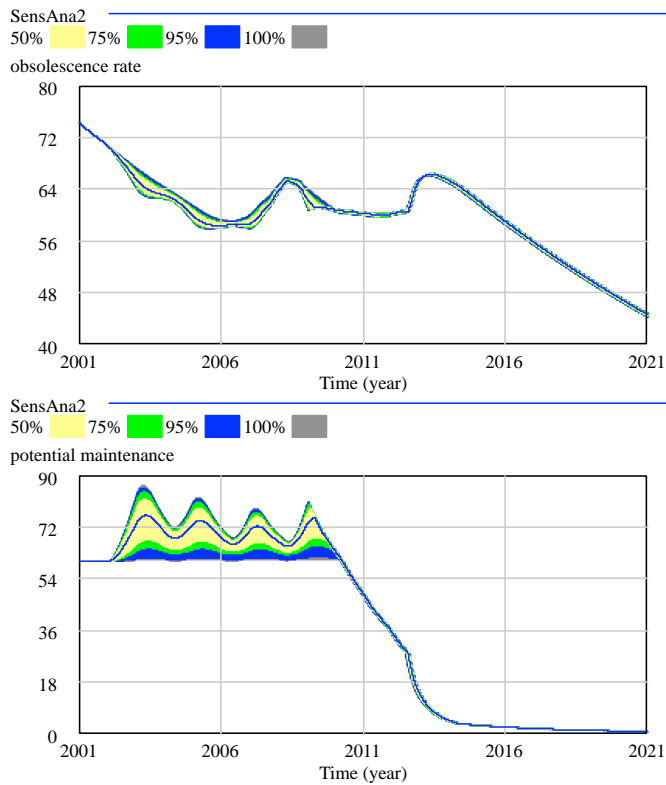
	Base case values	Ranges of Uncertainty
1.	% annual revenue ringfenced per year= 0.4	Uniform (0,0.8)

Motivation:

The percentage of annual revenue ringfenced per year could conceivably drop to zero over periods of financial crisis in the municipality. It is possible for the municipality to ringfence a higher proportion of revenue, but it is unlikely that the municipality would reserve more than 80% of water-related revenue for expenditure in the municipal water unit.



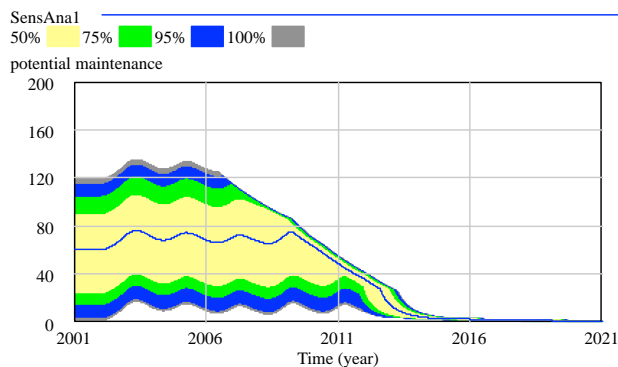
Supplementary material 3 – sensitivity analysis



HENCE, effect of ringfencing is MORE minor than expected – because potential billable water still to small (i.e. water services rely on grants and other income).

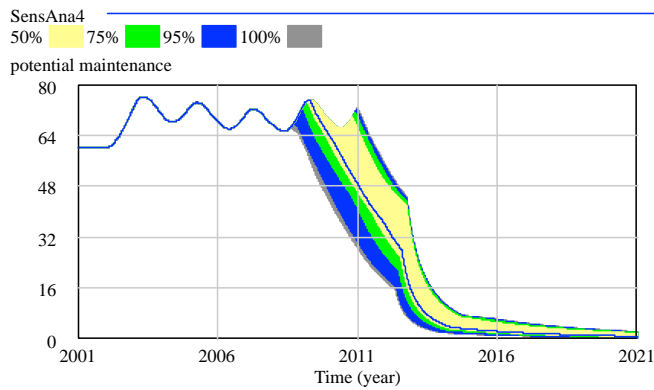
Argument: ‘potential maintenance’ more greatly affected by availability of ‘annual municipal financial bailout’ than it is affected by changes in the reference unit productivity

E.g. when testing sensitivity of annual muni. financial bailout:



Versus when testing sensitivity of reference unit productivity of staffing:

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3: Univariate analysis – average loss percentage

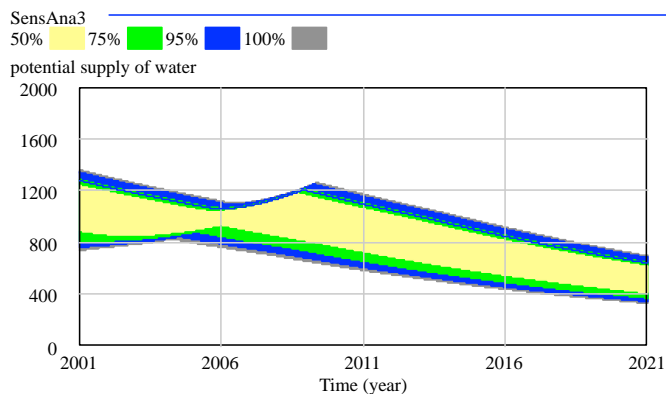
Run name: *SensAna3*

Variables saved as KPIs: Infrastructure capacity; potential supply of water; obsolescence rate; current total discrepancy

	Base case values	Ranges of Uncertainty
1.	Average loss percentage = 0.3	Uniform (0.25,0.6)

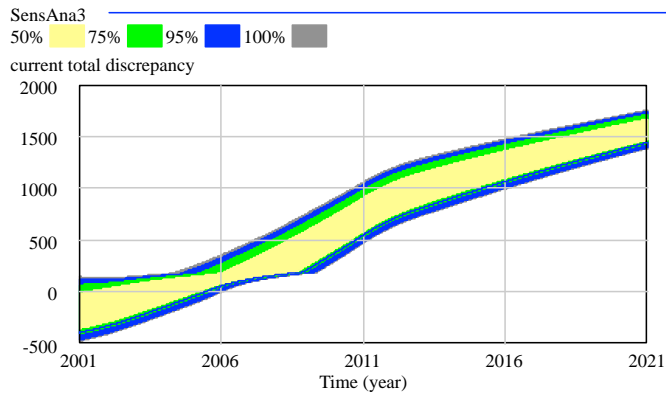
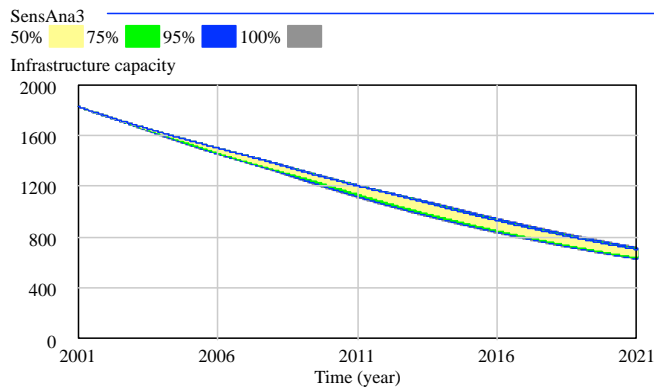
Motivation:

The average losses in the Greater Kirkwood region are estimated to be around 30% in the *MoF* model. Some estimates for the entire Sundays River Valley Municipality suggest that a total of 41% of the ‘system input volume’ of is non-revenue water.¹ The upper bound of water losses is therefore placed 1/3 higher in this sensitivity analysis, catering for a maximum of 60%. The conservative estimate of 25% is used as the minimum value.



¹ Wegelin, W. A., Siqalaba, Z., & Zondo, N. (2012). *Water Demand Management Strategy and Business Plan for Sundays River Valley Local Municipality*, p.4.

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4: Univariate analysis – reference unit productivity (staffing)

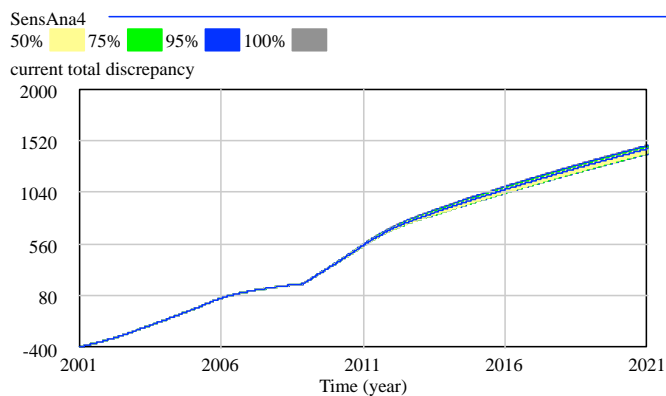
Run name: *SensAna4*

Variables saved as KPIs: Infrastructure capacity; potential supply of water; obsolescence rate; current total discrepancy; potential maintenance

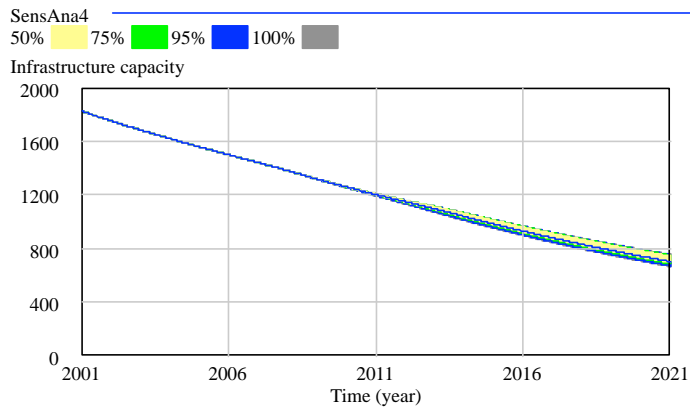
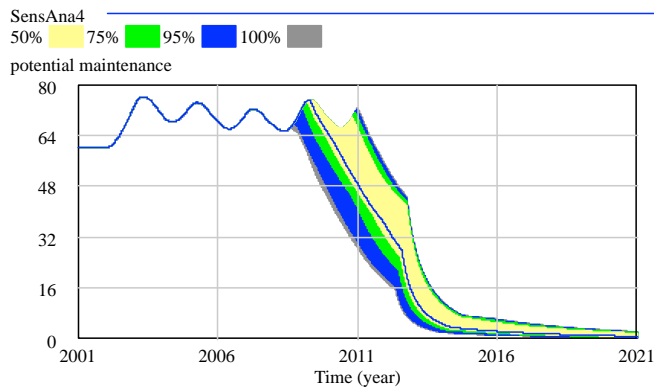
	Base case values	Ranges of Uncertainty
1.	Reference unit productivity = 20 ML/year/year	Uniform (10,50)

Motivation:

Range of uncertainty accounts for maximum productivity of 2.5 times the reference productivity, and a minimum of 50%.



Supplementary material 3 – sensitivity analysis



5: Multivariate analysis – staffing: reference unit productivity and hiring rate

Run name: *SensAna5*

Variable(s) saved: Infrastructure capacity; current total discrepancy; potential maintenance; technical staff capacity constraints on maintenance; technical staff capacity constraints on secondary activities

	Base case values	Ranges of Uncertainty
1.	Reference unit productivity = 20 ML/year/year	Uniform (10,50)
2.	hiring rate = 0.5	Uniform (0, 2)

Motivation:

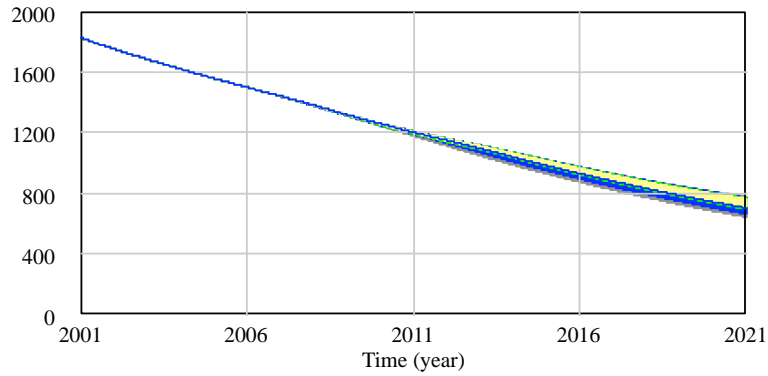
Range of uncertainty accounts for maximum productivity of 2.5 times the reference productivity, and a minimum of 50% (same as the fourth sensitivity analysis). In addition, the hiring rate is adjusted to allow for no hiring (as a minimum value over times of municipal crises) and maximum hiring of four times the standard value (if municipal staffing budget was expanded and qualified officials employed).

Supplementary material 3 – sensitivity analysis

SensAna5

50% 75% 95% 100%

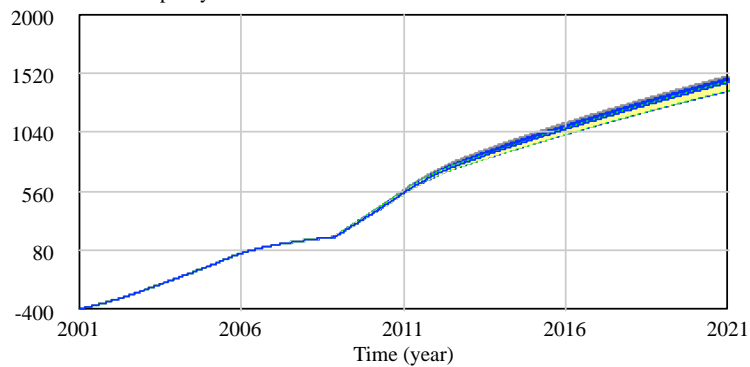
Infrastructure capacity



SensAna5

50% 75% 95% 100%

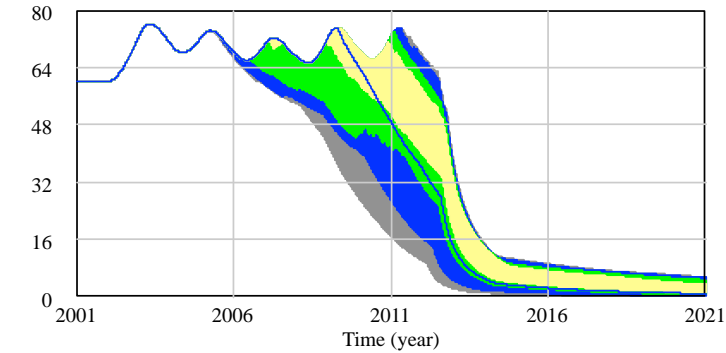
current total discrepancy



SensAna5

50% 75% 95% 100%

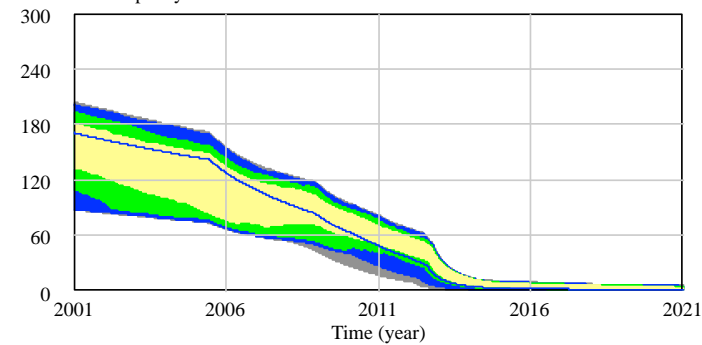
potential maintenance



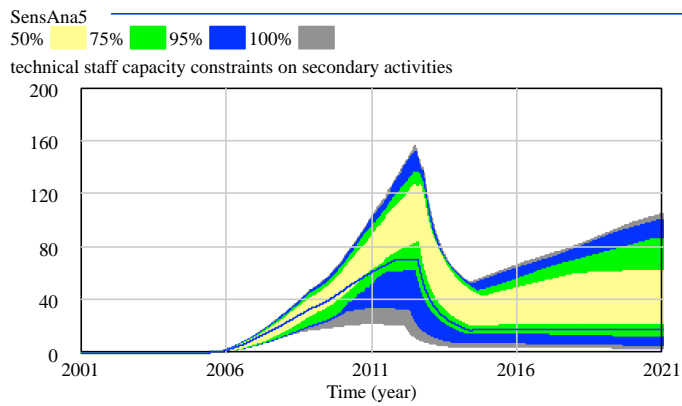
SensAna5

50% 75% 95% 100%

technical staff capacity constraints on maintenance



Supplementary material 3 – sensitivity analysis



6: Multivariate analysis – water demand management techniques

Run name: *SensAna6*

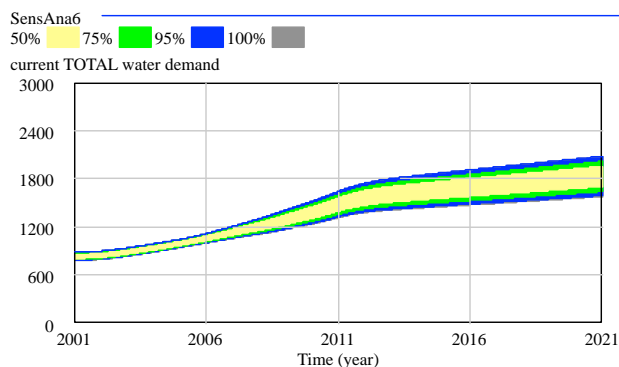
Variables saved as KPIs: Infrastructure capacity; current total discrepancy; potential maintenance; technical staff capacity constraints on maintenance; technical staff capacity constraints on secondary activities

	Base case values	Ranges of Uncertainty
1.	Average annual water use per connected household = 0.347	Uniform (0.25,0.347)
2.	Average loss percentage = 0.3	Uniform (0.2,0.3)

Motivation:

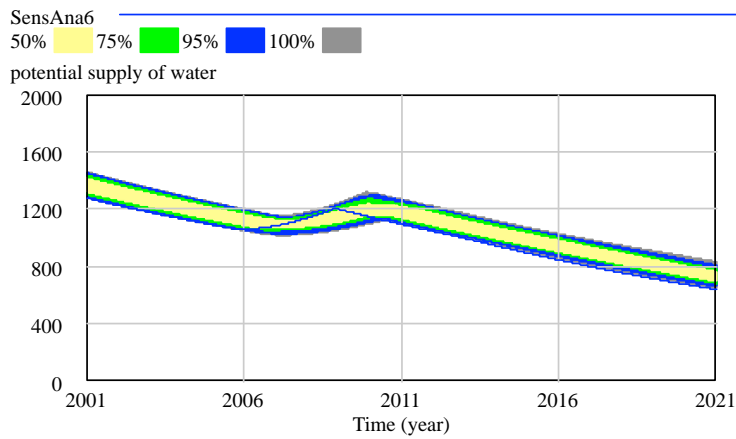
Water demand management and water conservation programmes are tested here in order to see the effect of reducing both the bulk water losses and the average annual water use per connected household.

Total water demand fluctuates as expected:

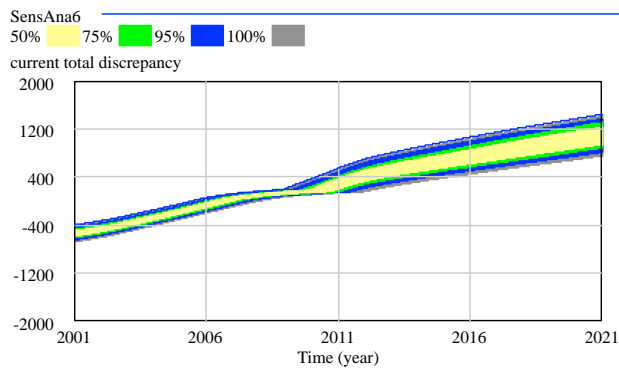


Potential supply of water increases as a result of less water losses;

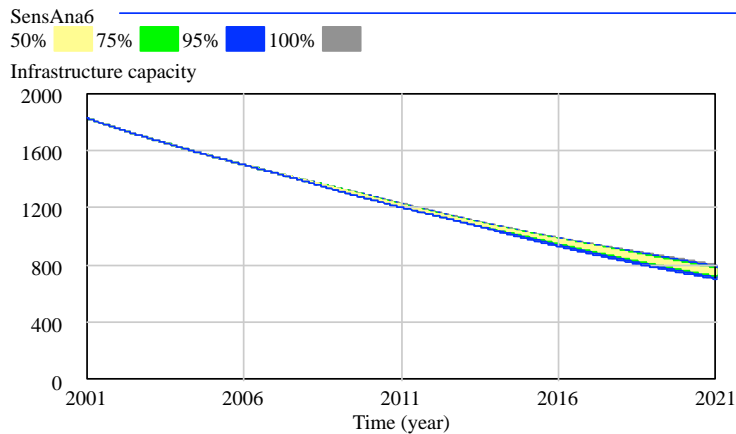
Supplementary material 3 – sensitivity analysis



And therefore total discrepancy is lower (as you would expect): but the



But infrastructure capacity largely unaffected:



7: Univariate analysis – average refurbishment and construction time

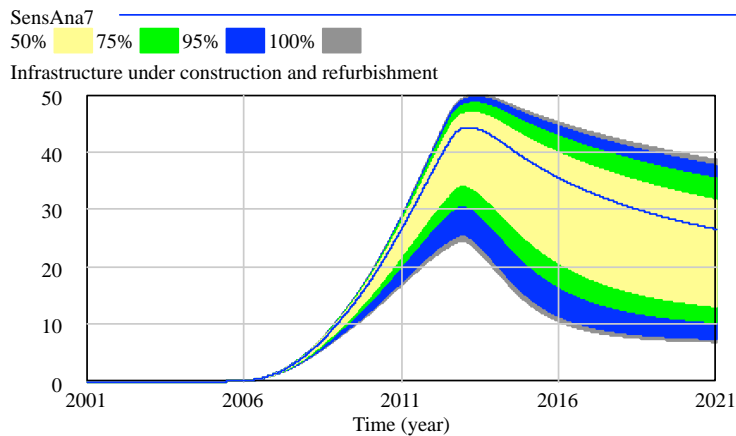
Run name: *SensAna7*

Variables saved as KPIs: Infrastructure capacity; current total discrepancy; potential supply of water; infrastructure under construction and refurbishment

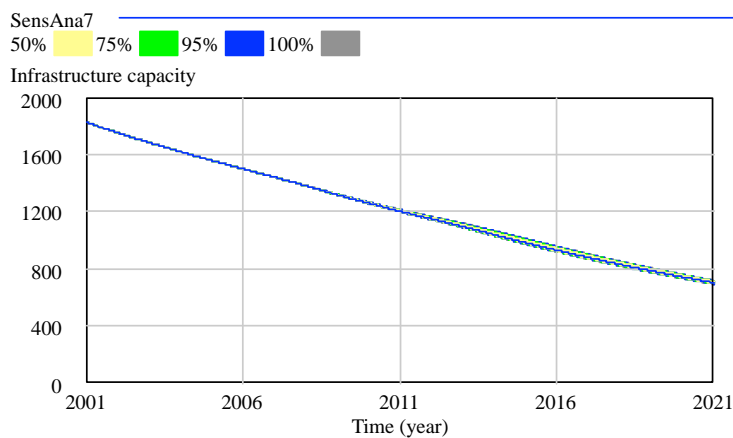
	Base case values	Ranges of Uncertainty
7.	Average refurbishment and construction time = 5 years	Uniform (1.5,7.5)

Motivation:

It is conceivable that the municipality could refurbish and construct water supply infrastructure more quickly in an emergency situation when it is faced with a supply-demand gap. A value of 1.5 years is selected as the minimum period of time, if the work was fast-tracked. A value of 7.5 years (50% longer than the average time) is selected for the maximum time.

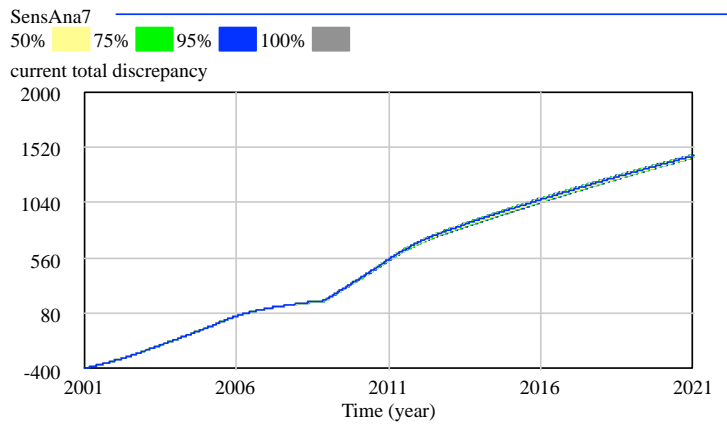


But, little change to infrastructure capacity:



and current total discrepancy remains stable:

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Conclusion:

The sensitivity analysis demonstrated that staffing capacity exerted a constraining effect over the longer term, and that only minor changes occurred in infrastructure capacity. In summary, no individual measure was found to be effective in addressing the fundamental model behaviour of declining infrastructural capacity.

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