An approach to measuring resilience to manage water supply systems

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Normal provision of water service

DURATION
AND
SEVERITY

DEFINITION					
	(White House, 2013)	(Henry y Ramírez, 2012)	(Petit et al., 2013)	(Fitzgerald, 2009)	(EPA, 2015)
Preparedness	X		X		X
Anticipate risk				X	
Absorb energy					
Mitigation			X		X
Adaptation	X				
Assessment of vulnerability					X
Limit impact				X	
Response capacity			X		
Risk management					X
Support	X				
Recovery	X	X	X	X	

TOOLS	
Raise awareness	(Travers, 2010)
Climate change	(EPA, 2012)
Contamination waring systems	(Murray et al., 2010)
Risk management	(Brashear y Jones, 2010)

INDICATORS	
Argonne National Laboratory Resilience Index	(Petit et al., 2013)
Resilience Index	(Todini, 2000)
Modified Resilience Index	(Jayaram y Srinivasan, 2008)
Network Resilience Index	(Prasad y Park, 2004)

Resilience factor

MODELS			
Water quantity	X		
Water quality	X		
Water demand	X		
Other variables (pressure, etc.)	X		
Functionality of the system			X
Time to recover			X
Magnitude of events		X	
Duration of events		X	
	(Barnes et al., 2012)	(NIAC, 2009)	Tierney y Bruneau, 2007; Ayyub, 2014; Castet y Saleh, 2012)

Water discontinuity

Loss of service level

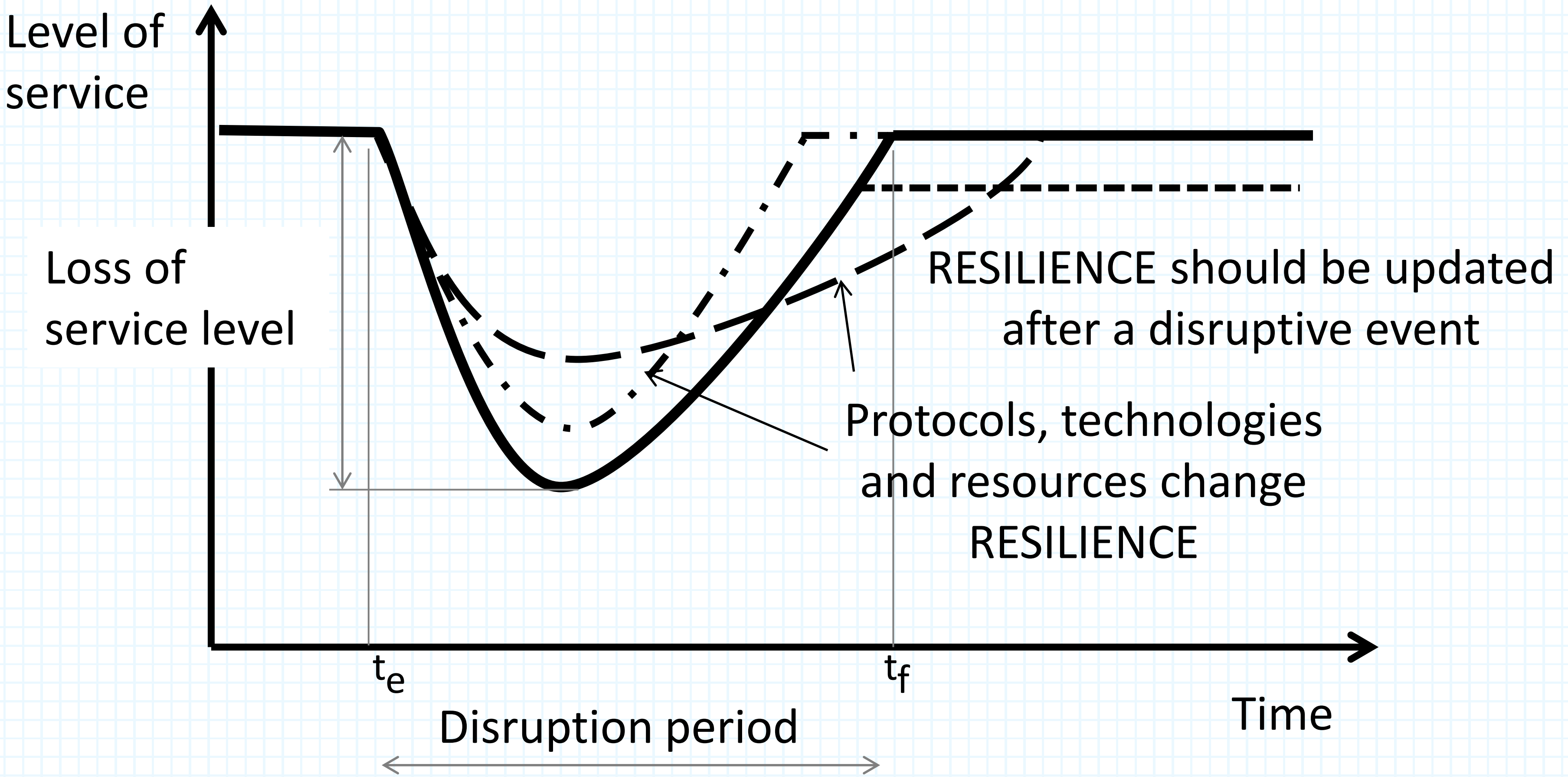
«We define RESILIENCE as the set of system CAPACITIES TO DELIMIT IMPACTS»

METHODOLOGY

We have defined

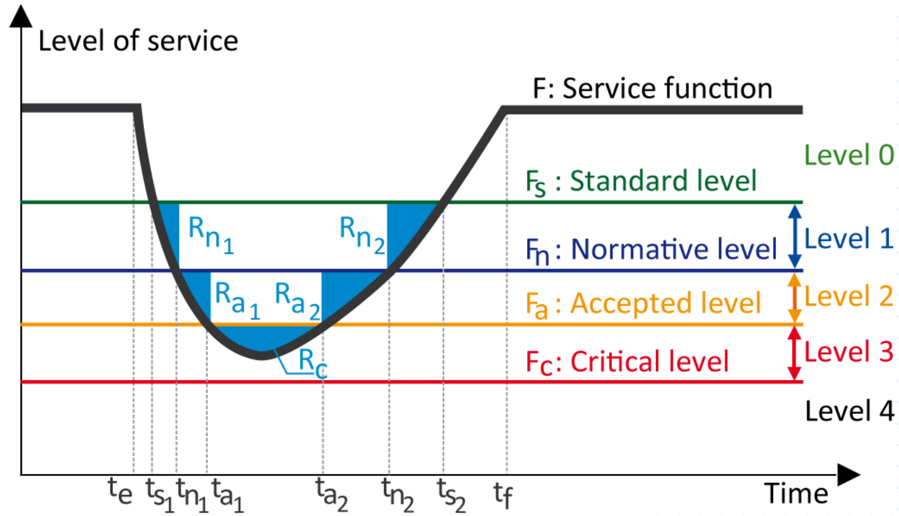
THREATS

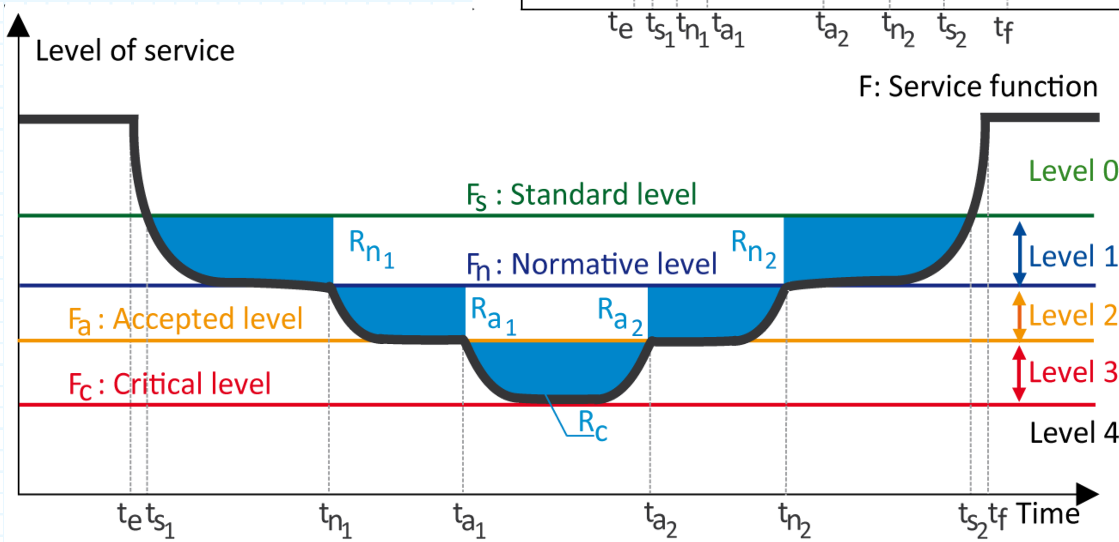
A. Water scarcity
B. Water supply discontinuity
C. Discontinuity of drinking water quality conditions
D. Discontinuity of hydraulic conditions



Level of service
Loss of service level
RESILIENCE should be updated after a disruptive event
Protocols, technologies and resources change RESILIENCE
t_e
t_f
Time
Disruption period

FAILURE THRESHOLDS





t_e : occurrence time

t_f : final recovery time

$t_{s,\,n,\,a\ 1\&2}$: intersection time with thresholds

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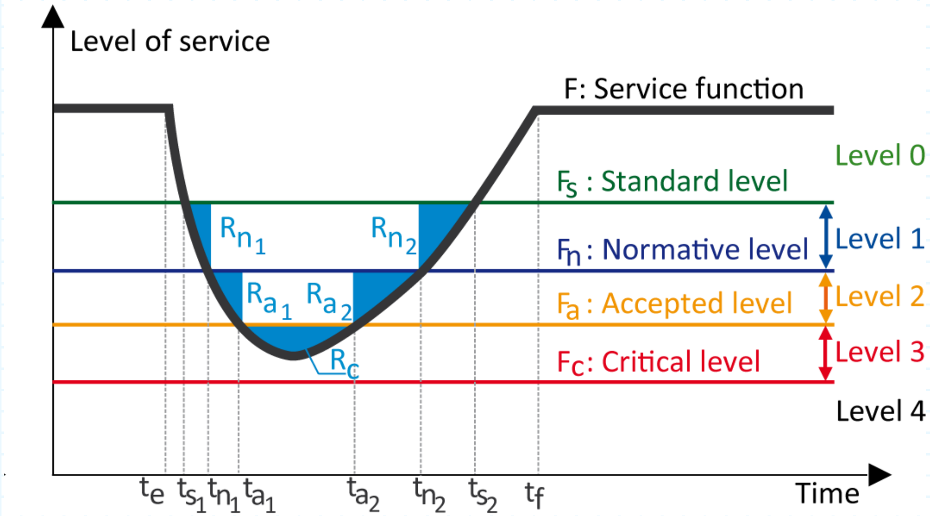
RESILIENCE FACTOR



$$\left(R_{f_n}\right)_A = \left(R_{f_{n1}}\right)_A + \left(R_{f_{n2}}\right)_A = \int_{t_{s_1}}^{t_{n_1}} \left(F_{S_A}(t) - F_A(t)\right) \bullet dt + \int_{t_{n_2}}^{t_{s_2}} \left(F_{S_A}(t) - F_A(t)\right) \bullet dt$$

$$\left(R_{f_a}\right)_A = \left(R_{f_{a1}}\right)_A + \left(R_{f_{a2}}\right)_A = \int_{t_{n_1}}^{t_{a_1}} \left(F_{n_A}(t) - F_A(t)\right) \bullet dt + \int_{t_{a_2}}^{t_{n_2}} \left(F_{n_A}(t) - F_A(t)\right) \bullet dt$$

$$\left(R_{f_c}\right)_A = \int_{t_{a_1}}^{t_{a_2}} \left(F_{a_A}(t) - F_A(t)\right) \bullet dt$$

$$\left(R_f\right)_A = P_{n_A} \bullet \left(R_{f_n}\right)_A + P_{a_A} \bullet \left(R_{f_a}\right)_A + P_{c_A} \bullet \left(R_{f_c}\right)_A$$

$$R_f = R_{f_A} \bullet P_A + R_{f_B} \bullet P_B + R_{f_C} \bullet P_C + R_{f_D} \bullet P_D$$

CASE STUDY

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Public water company that manages the water cycle in the Autonomous Region of Madrid (Spain)

6,238,000

end-users

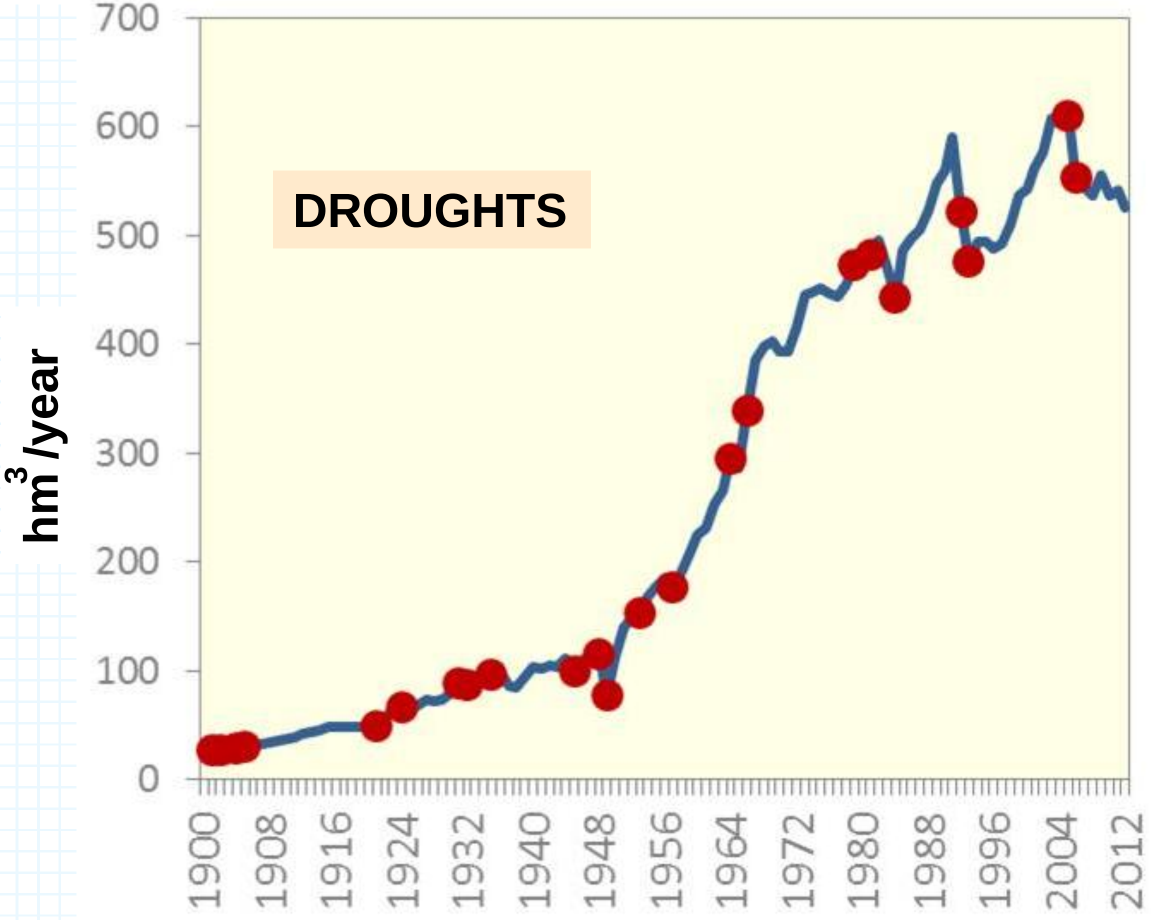
17,500 km

pipes

179

municipalities

Water scarcity



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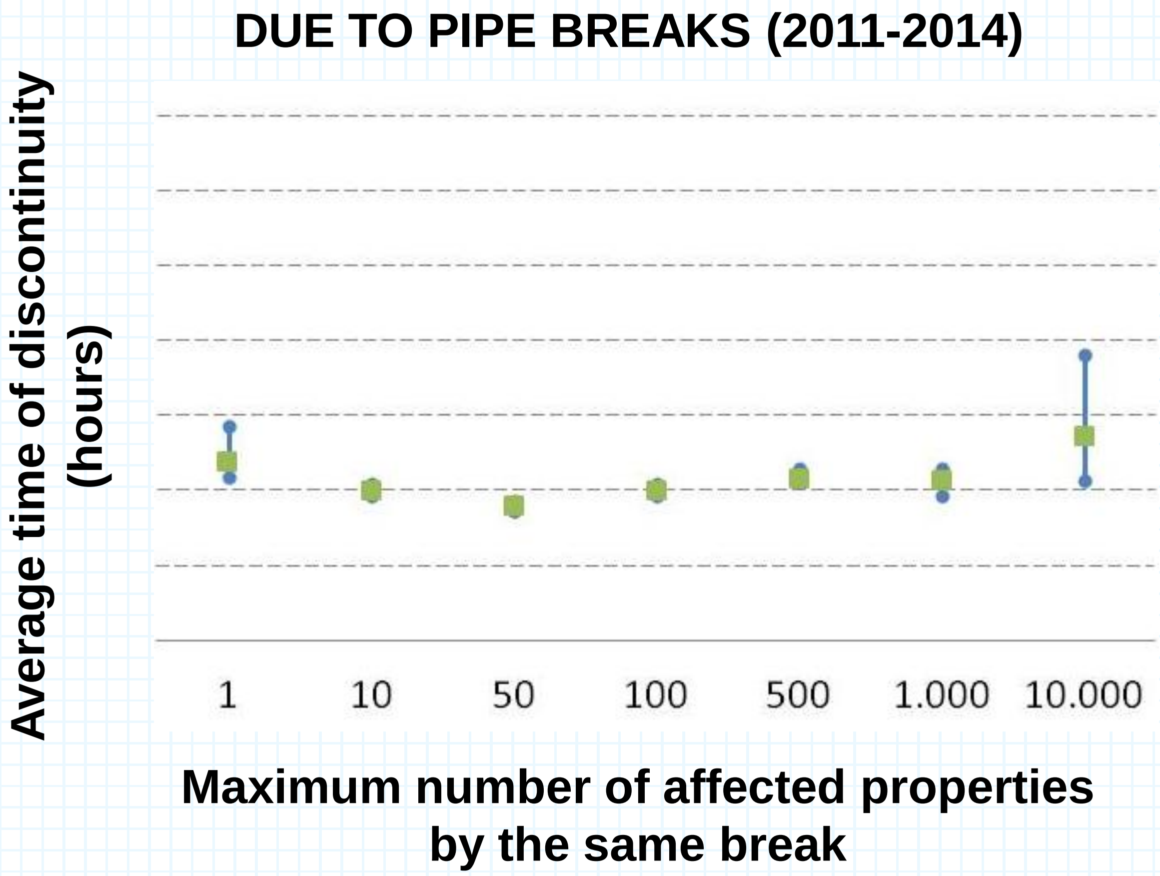
Water supply discontinuity



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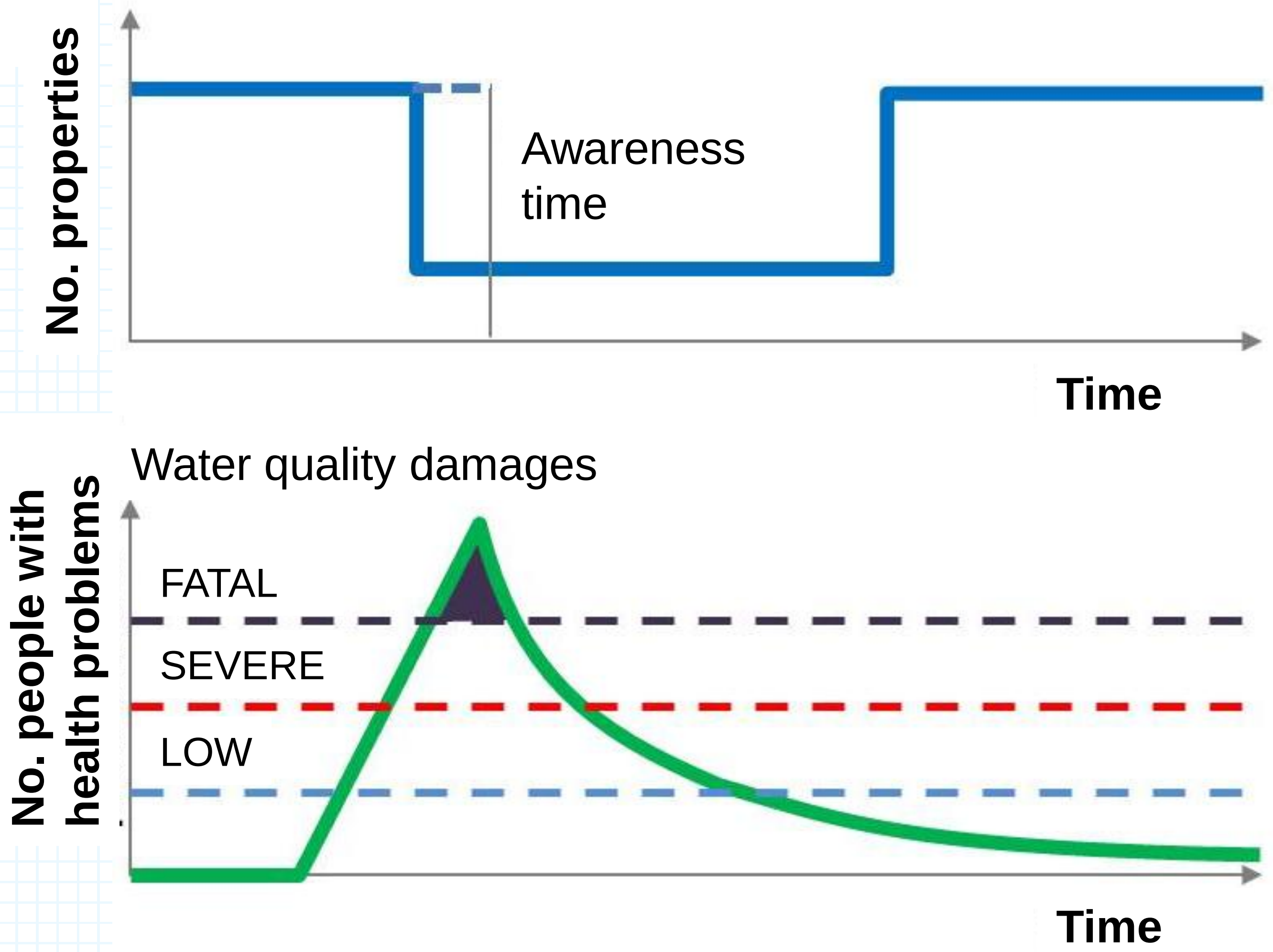
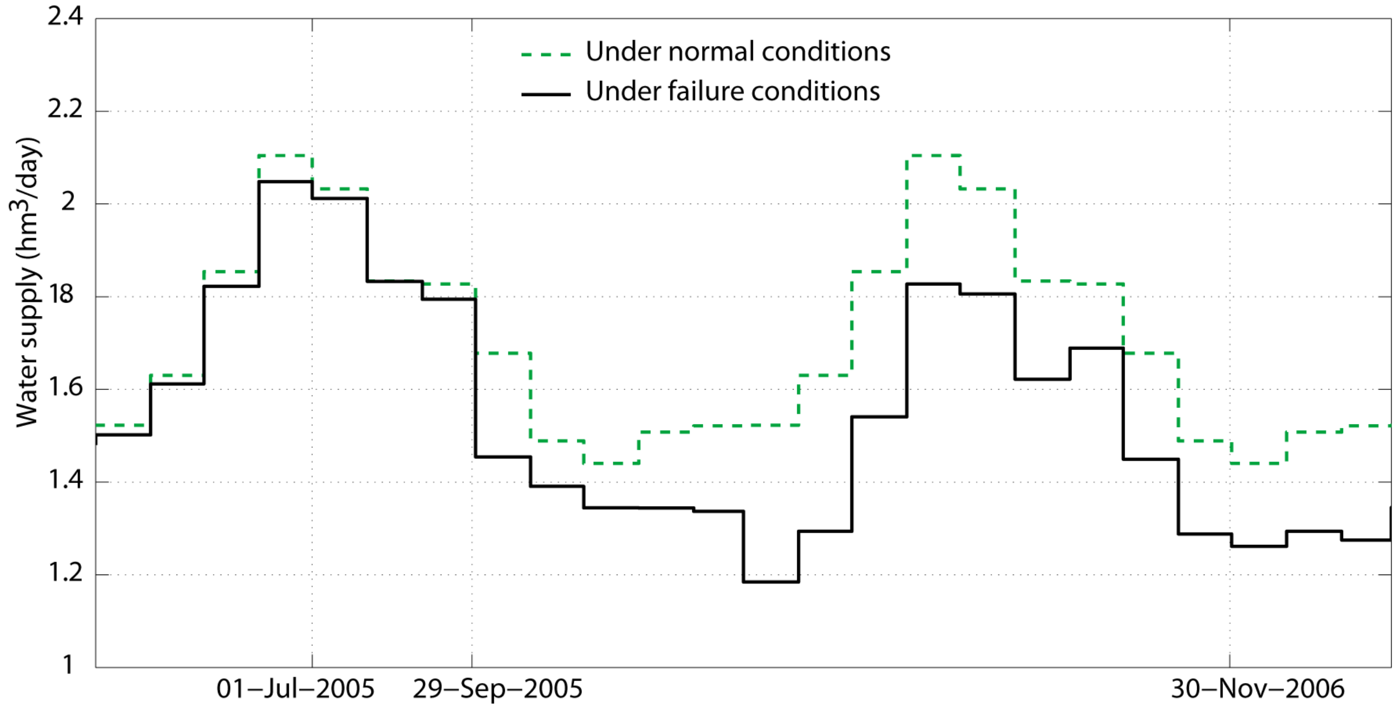
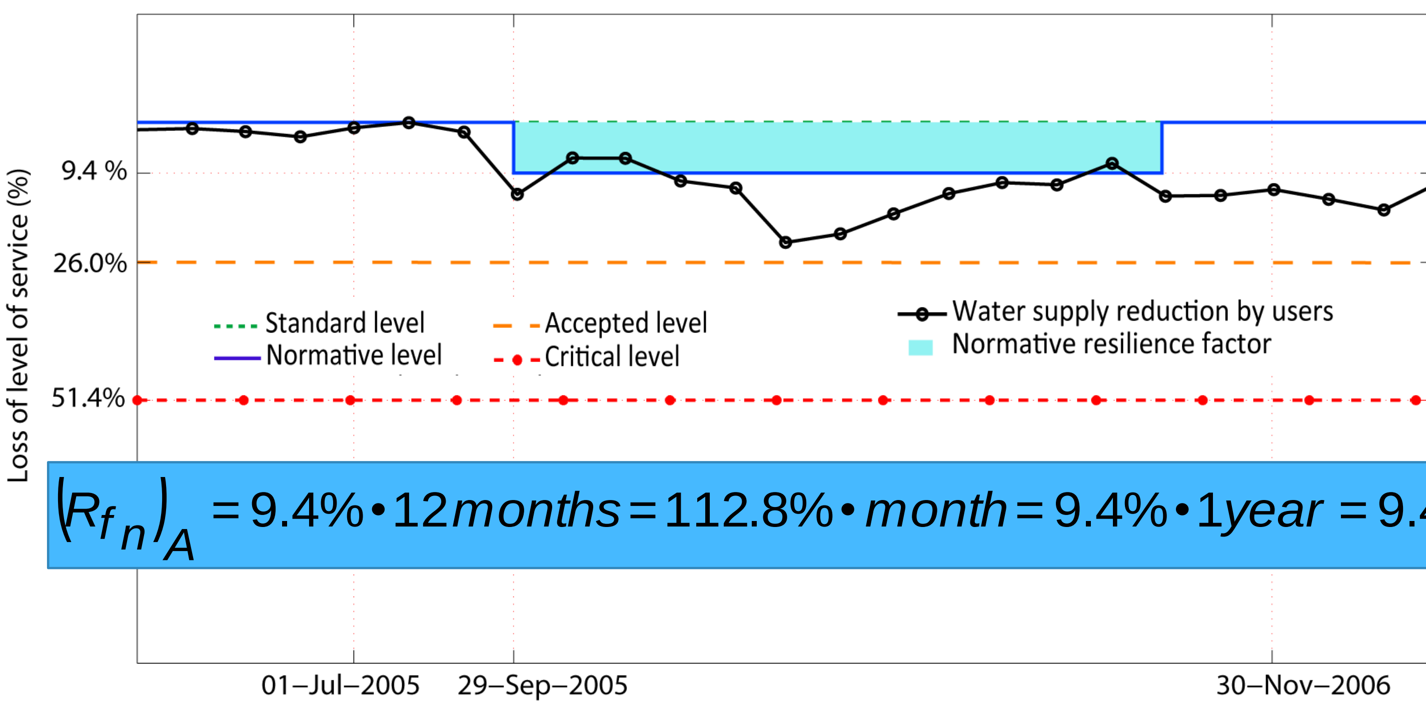
Discontinuity of drinking water quality conditions



RESULTS

DROUGHT





$$\left(R_{f_n}\right)_A = 9.4\% \cdot 12\,months = 112.8\% \cdot month = 9.4\% \cdot 1\,year = 9.4\% \cdot year$$

PROTOCOLS FOR CONTINGENCIES

PIPE BREAKS

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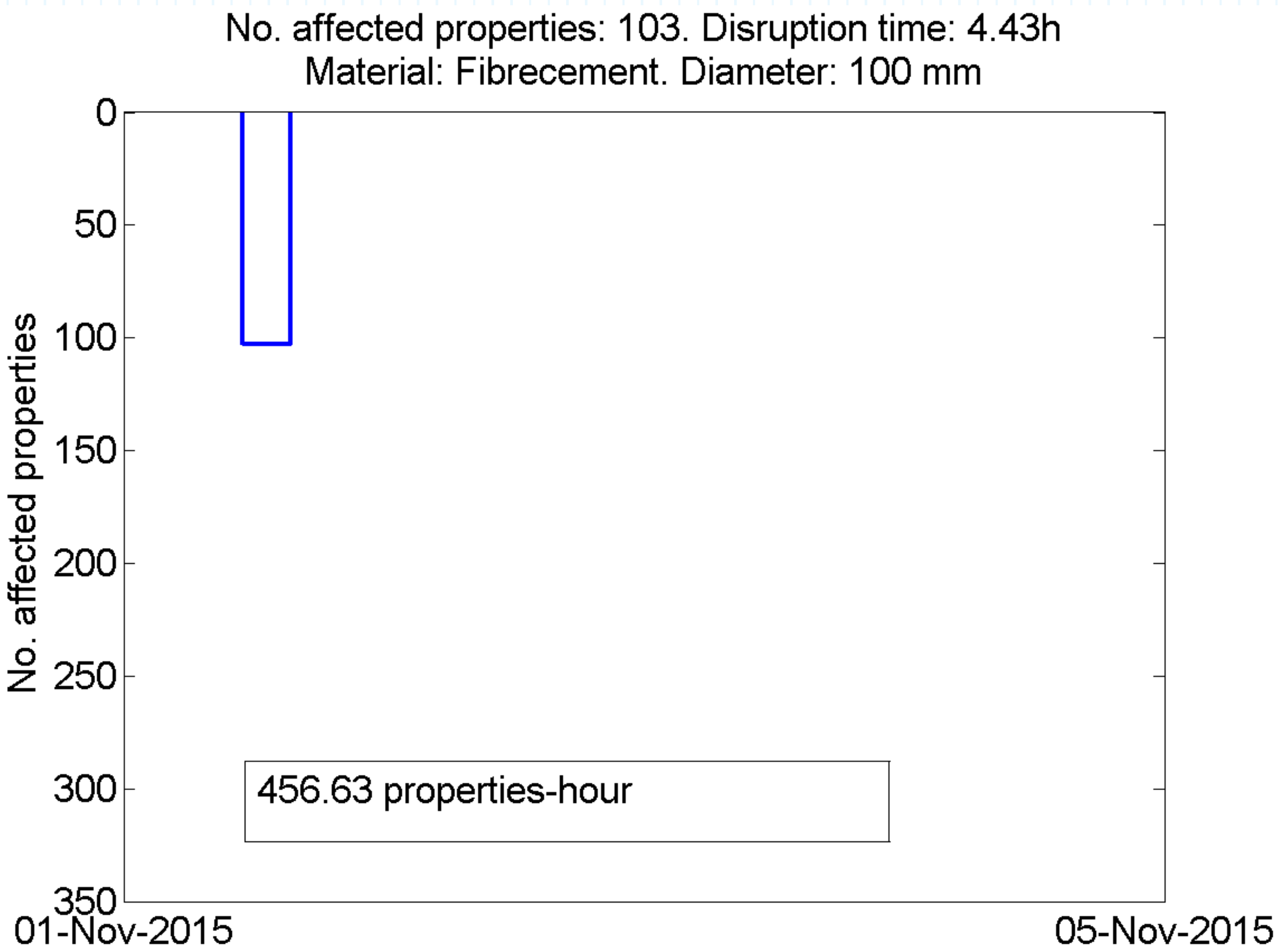

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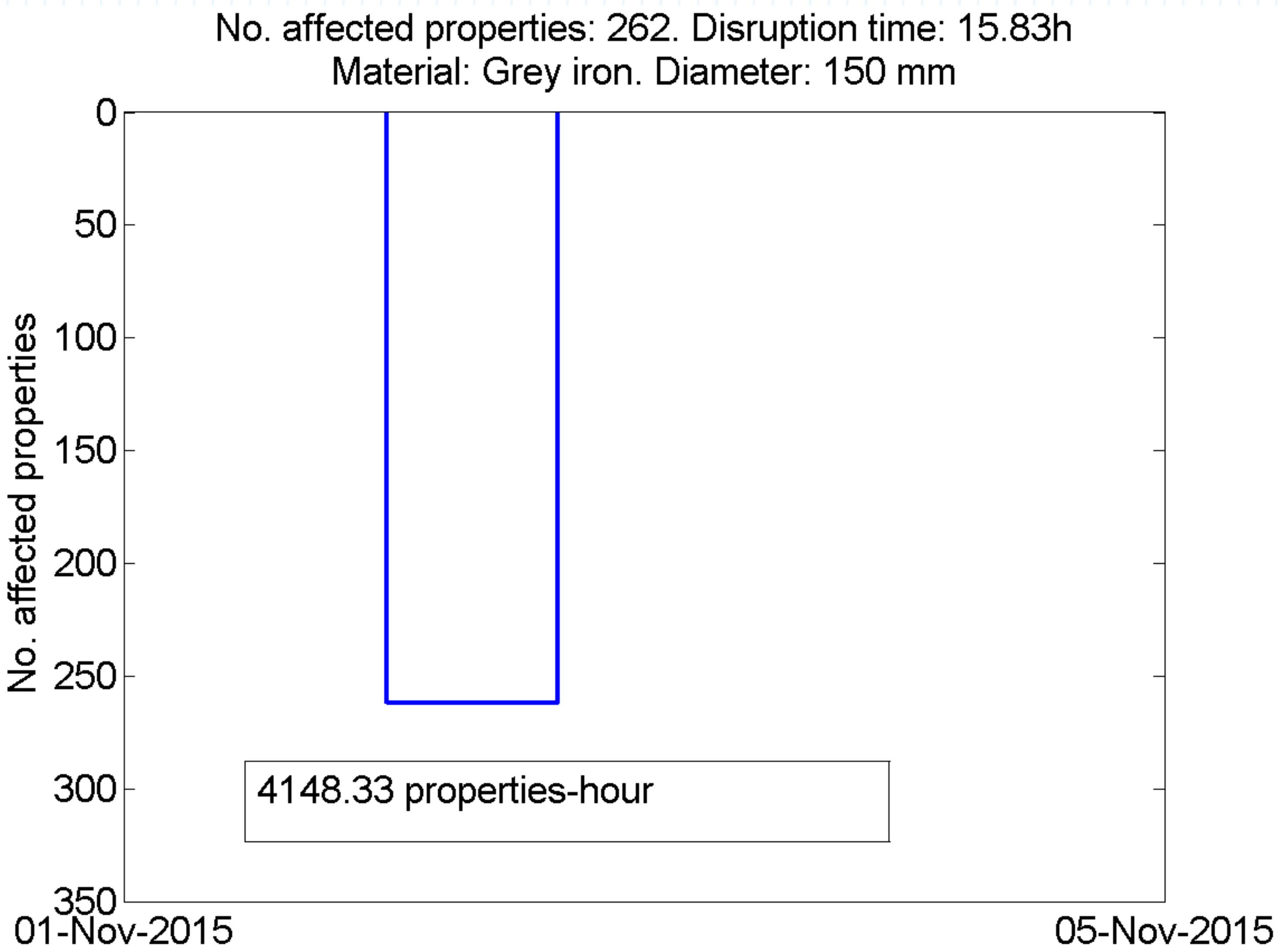

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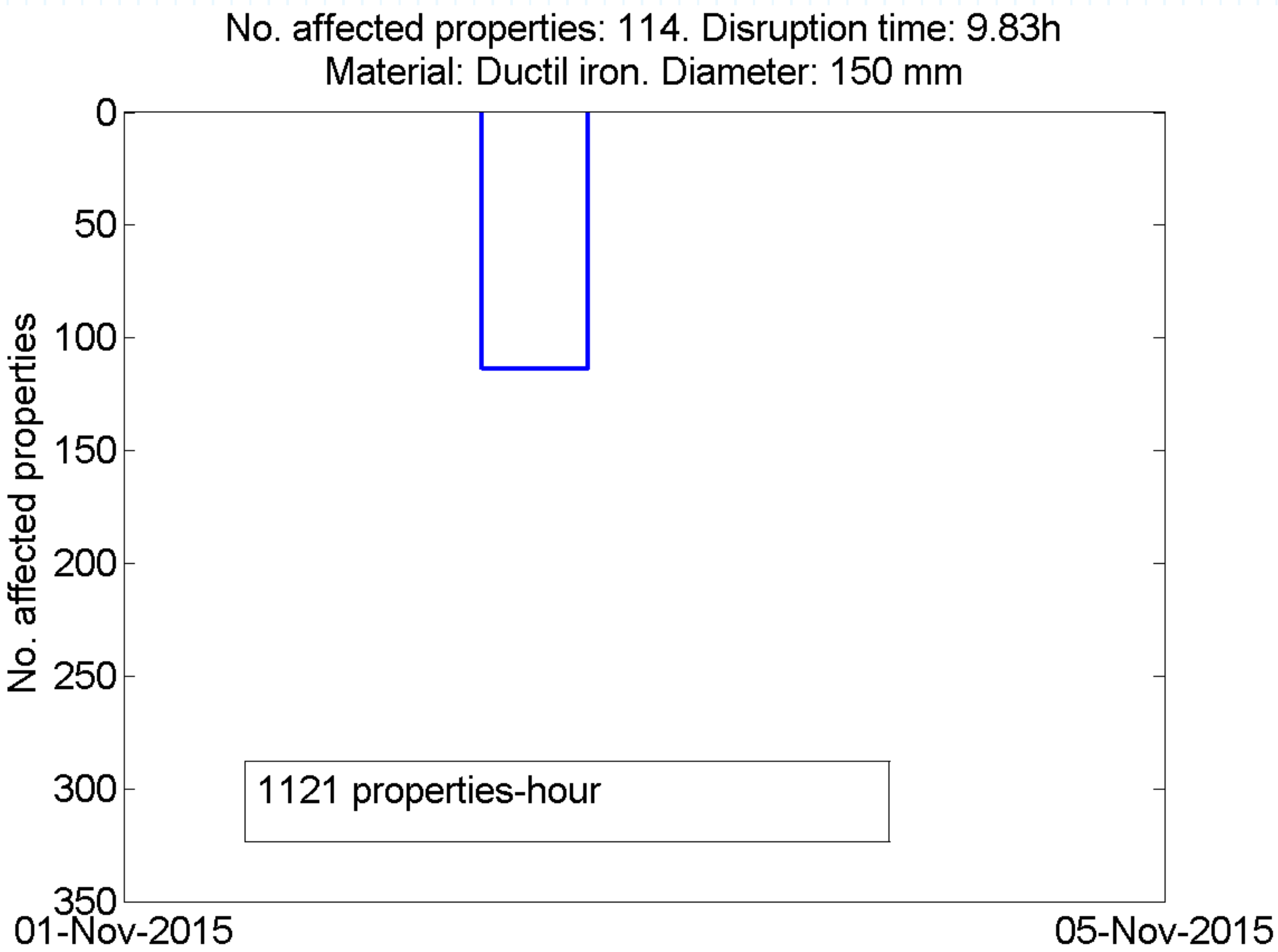

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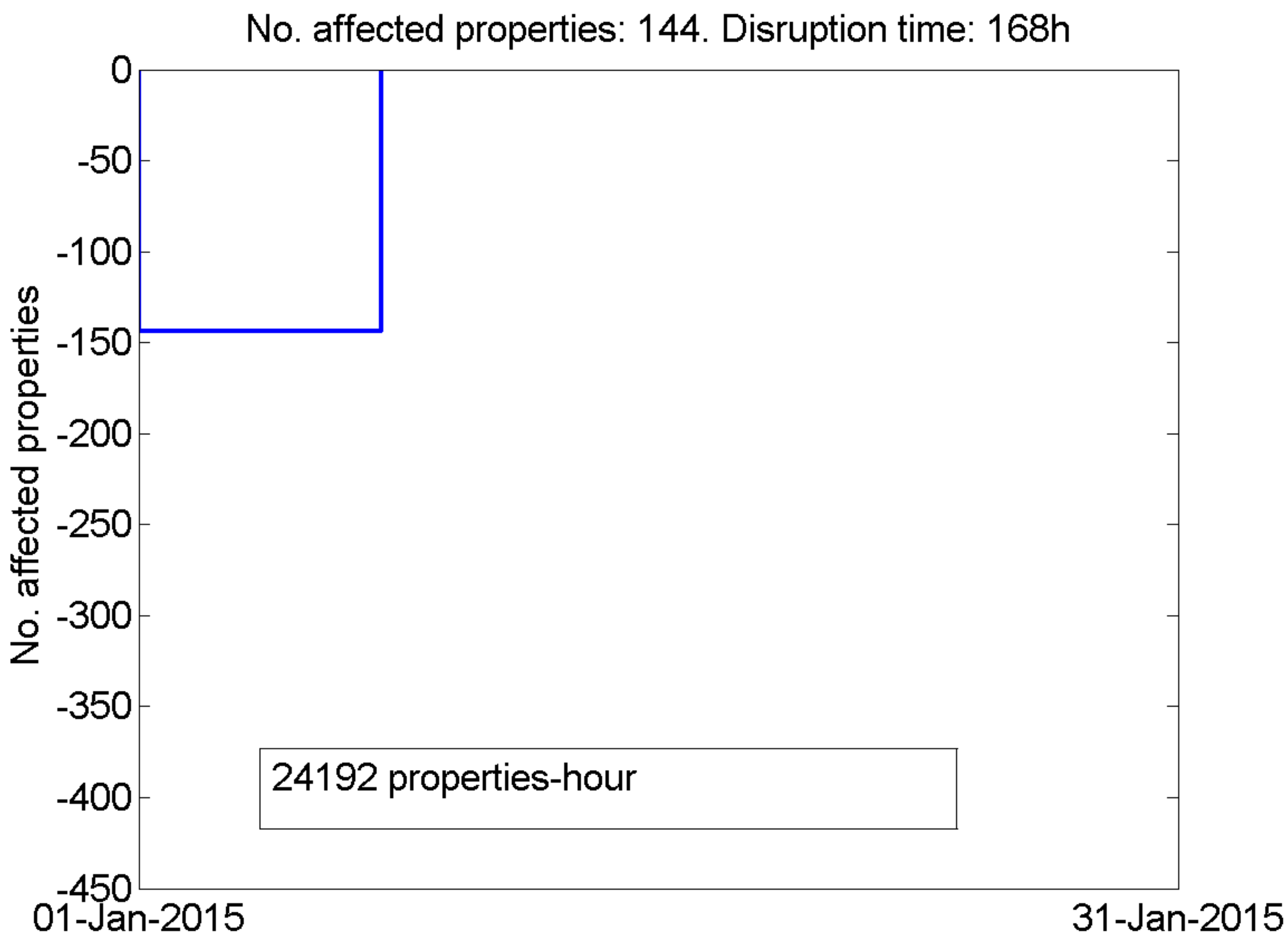
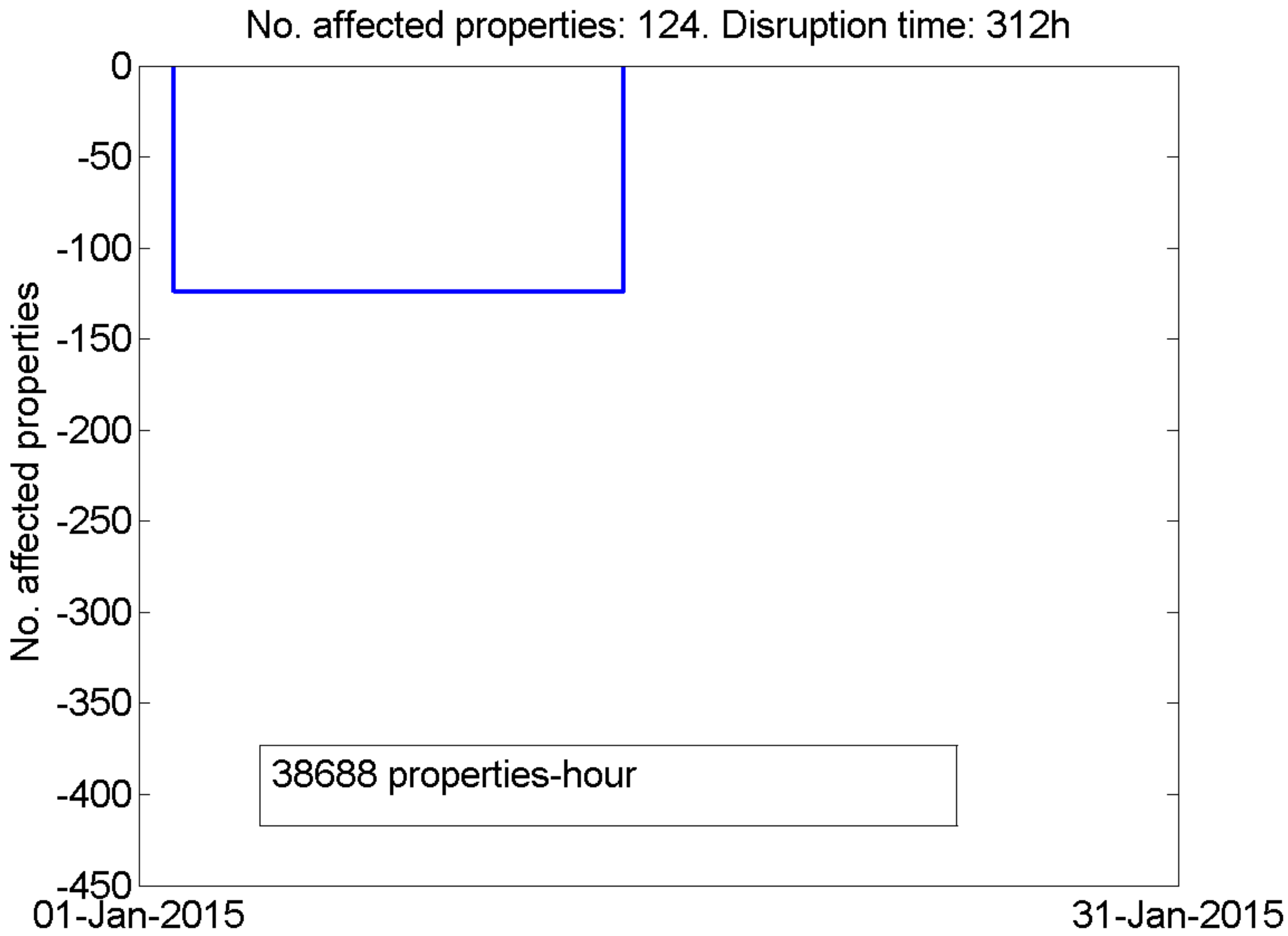
PROTOCOLS FOR CONTINGENCIES

WATER QUALITY FAILURES


No. affected properties: 144. Disruption time: 168h
No. affected properties
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
01-Jan-2015
31-Jan-2015
24192 properties-hour



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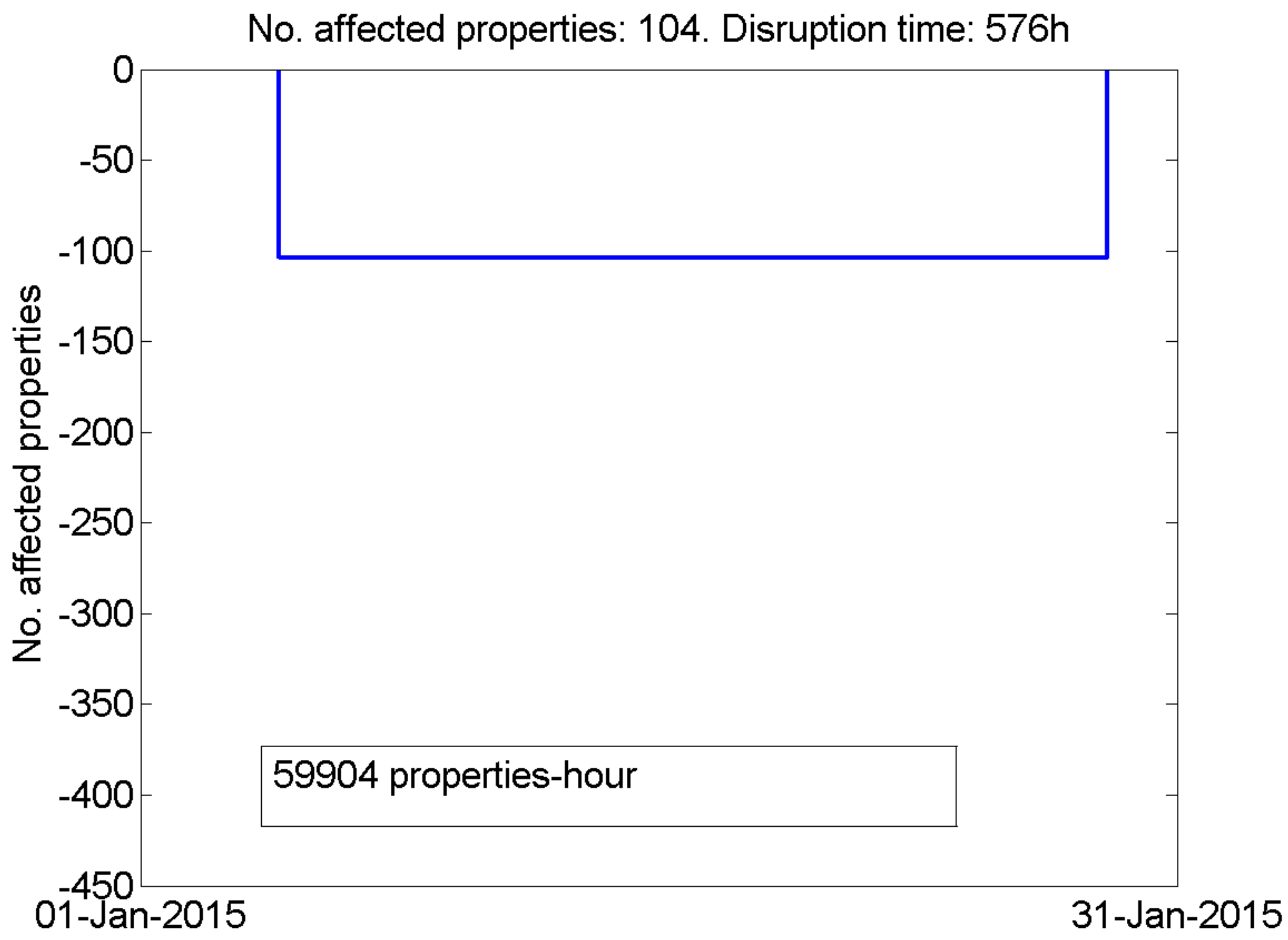
No. affected properties: 104. Disruption time: 576h
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
No. affected properties
59904 properties-hour
01-Jan-2015
31-Jan-2015

CONCLUSIONS

A new METHODOLOGY to measure RESILIENCE is developed

THREATS

FAILURE THRESHOLDS

The METHODOLOGY is applied to the water supply system of Canal Gestión water utility

DROUGHTS

PIPE BREAKS

WATER QUALITY FAILURES

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The METHODOLOGY allows:

Measuring RESILIENCE

Assessing PROTOCOLS

Planning INVESTMENTS

«It is possible to quantify RESILIENCE of a water supply system »

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