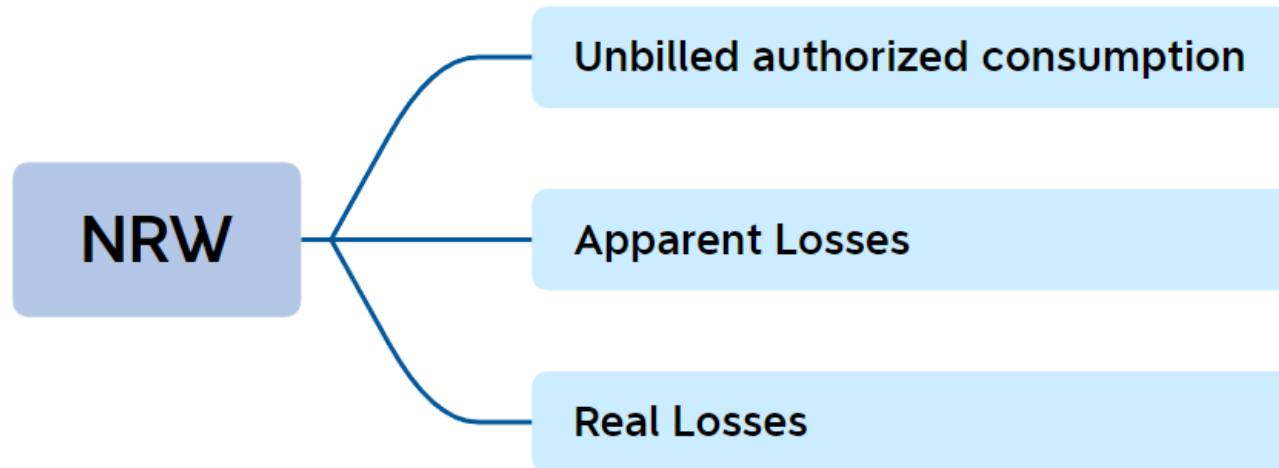


An integrated NRW target setting approach

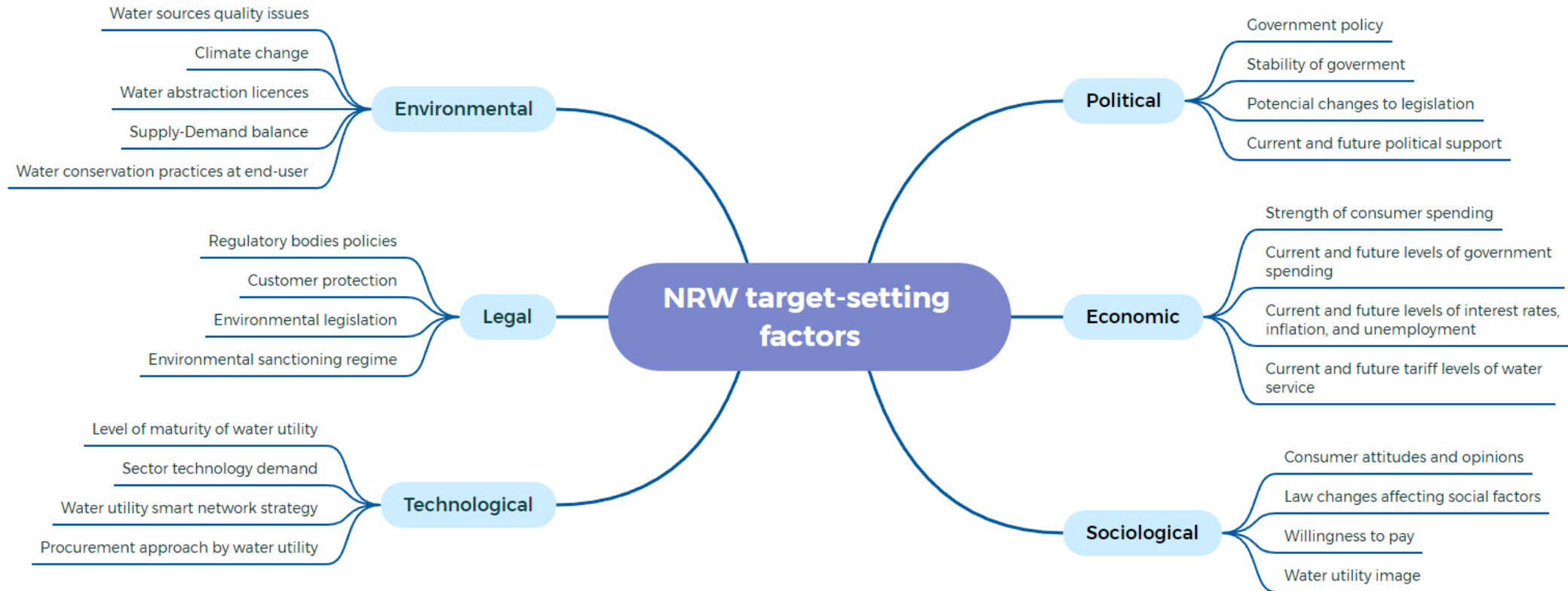
Fabio Garzón-Contreras
HydroFlux Colombia



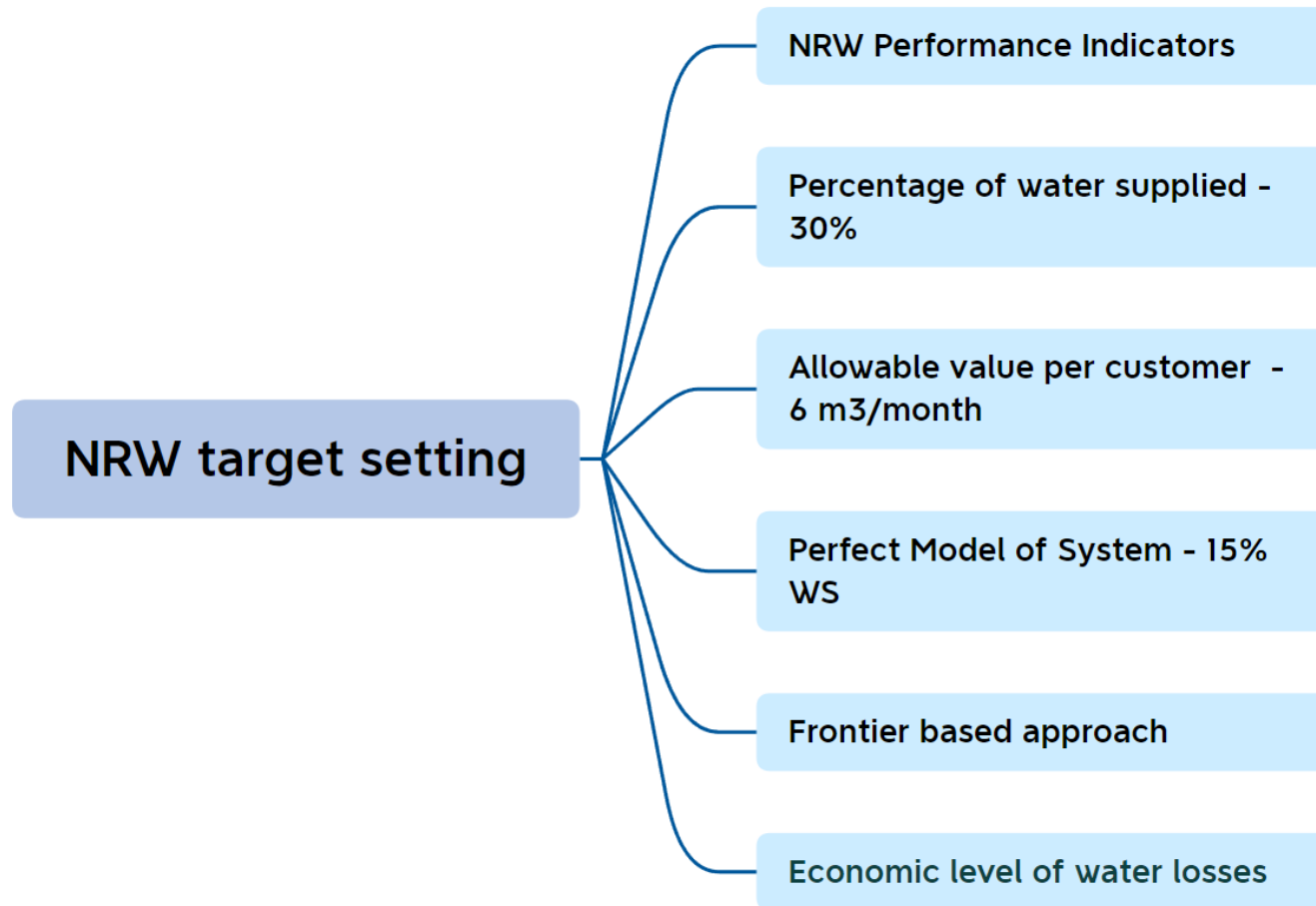
What is the optimal level of NRW?



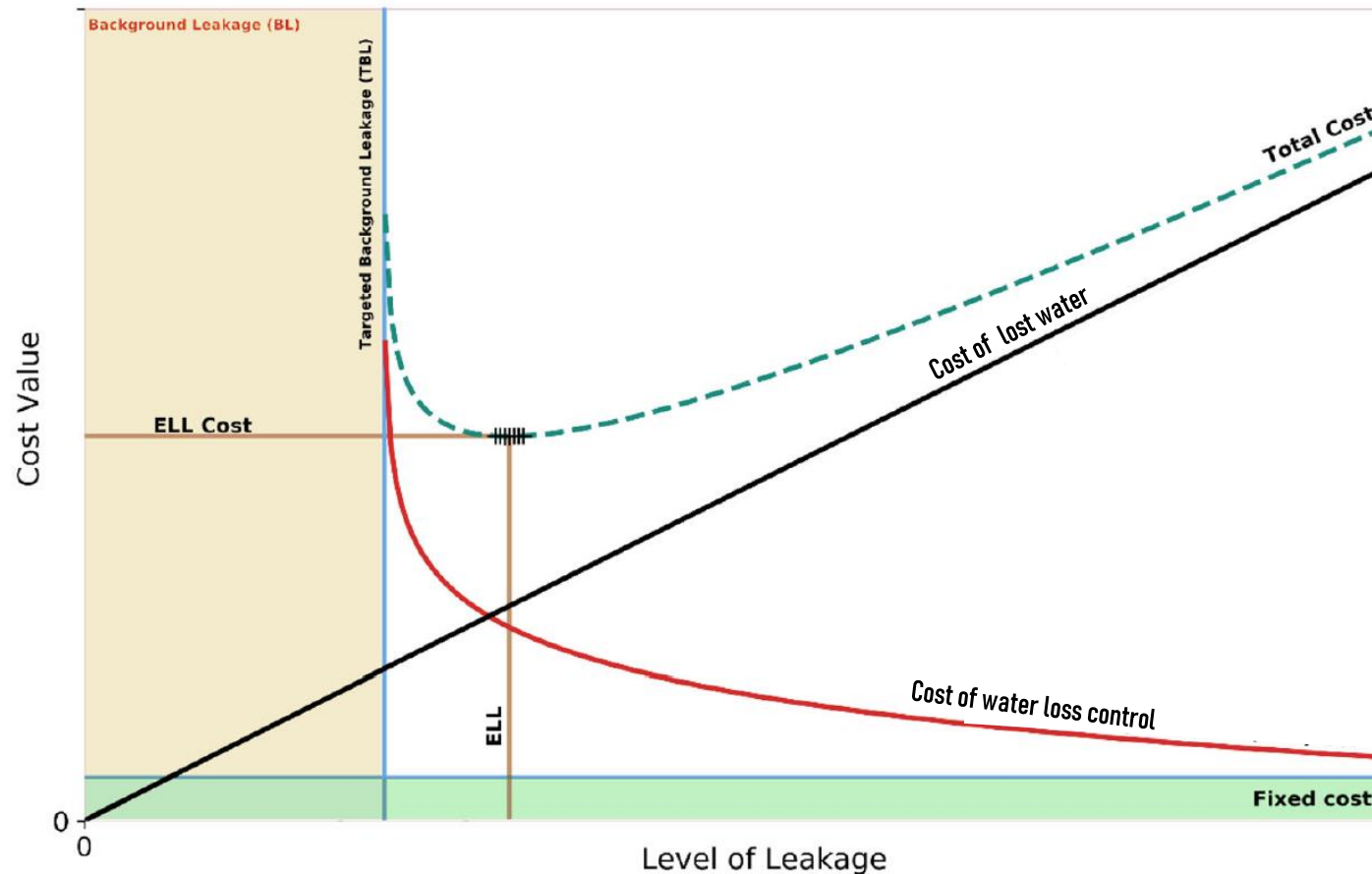
Factors affecting the NRW optimal level



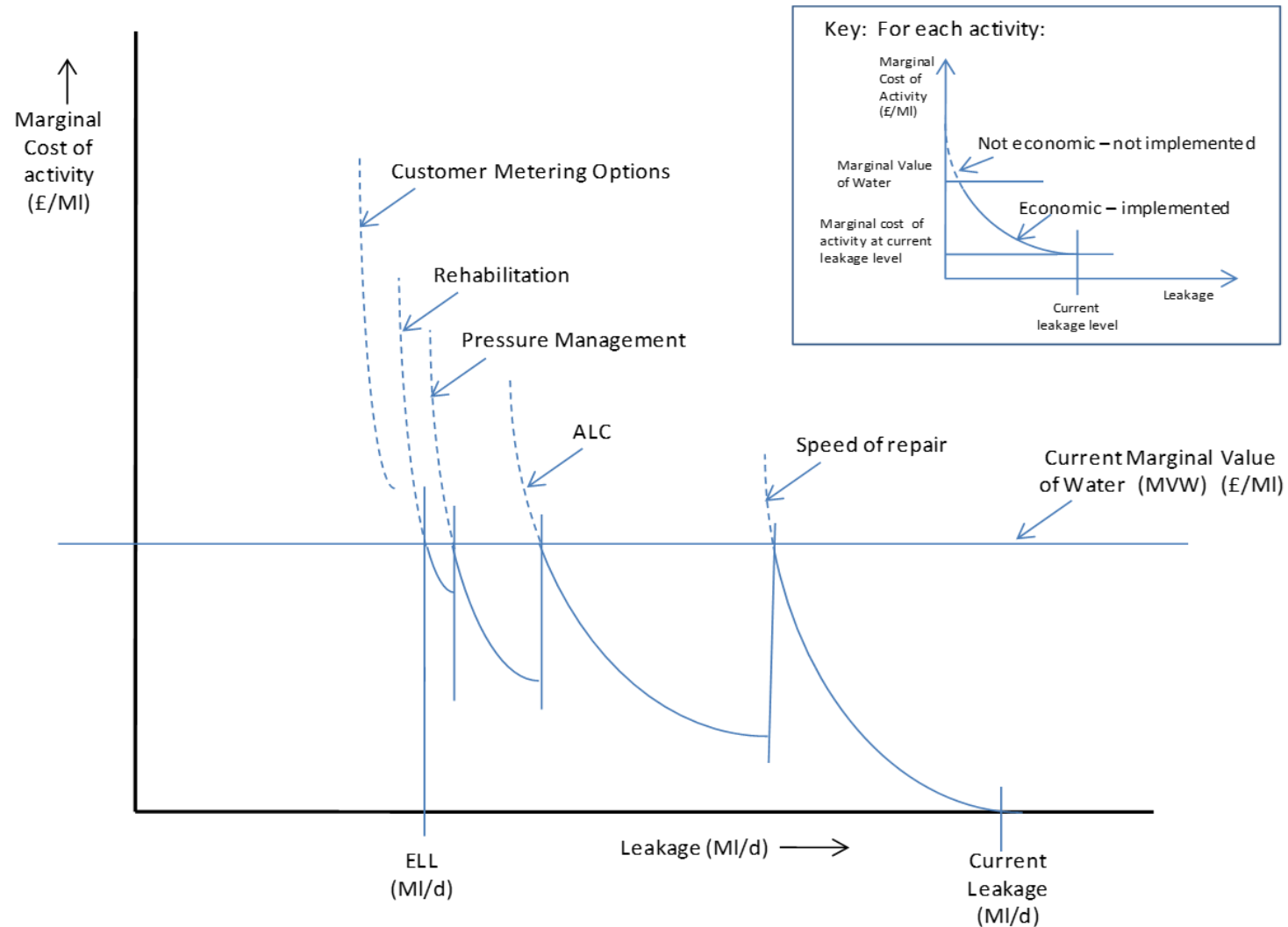
Alternative approaches to NRW target setting



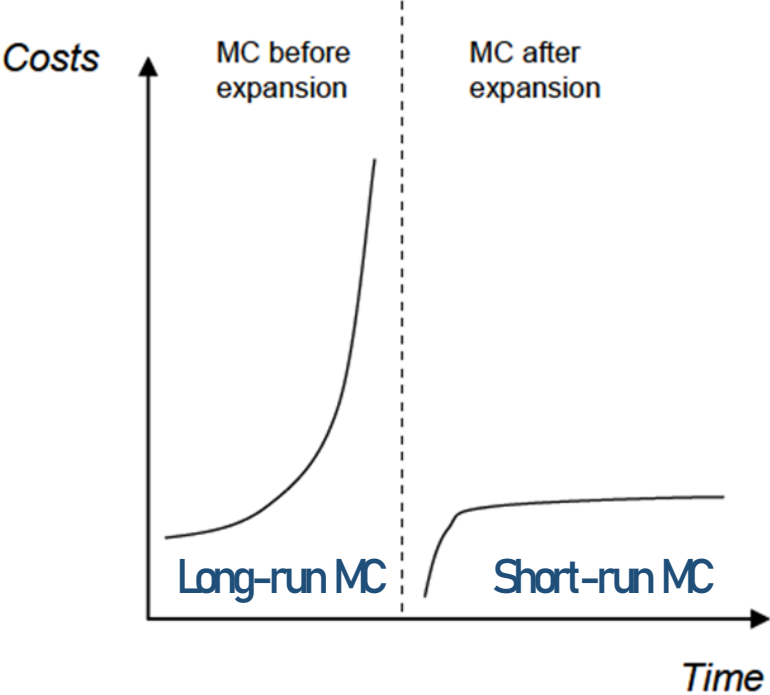
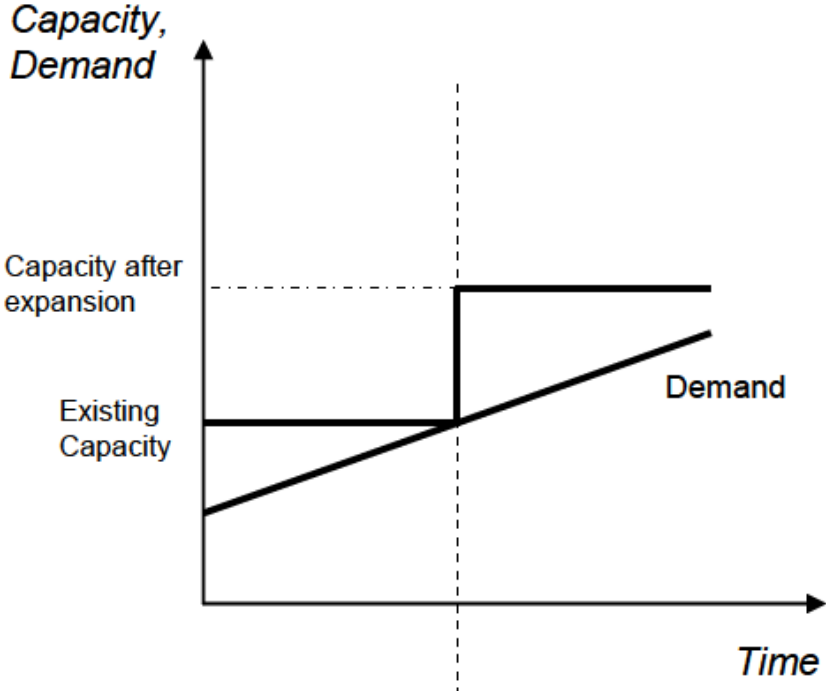
Economic level of water losses (ELWL)



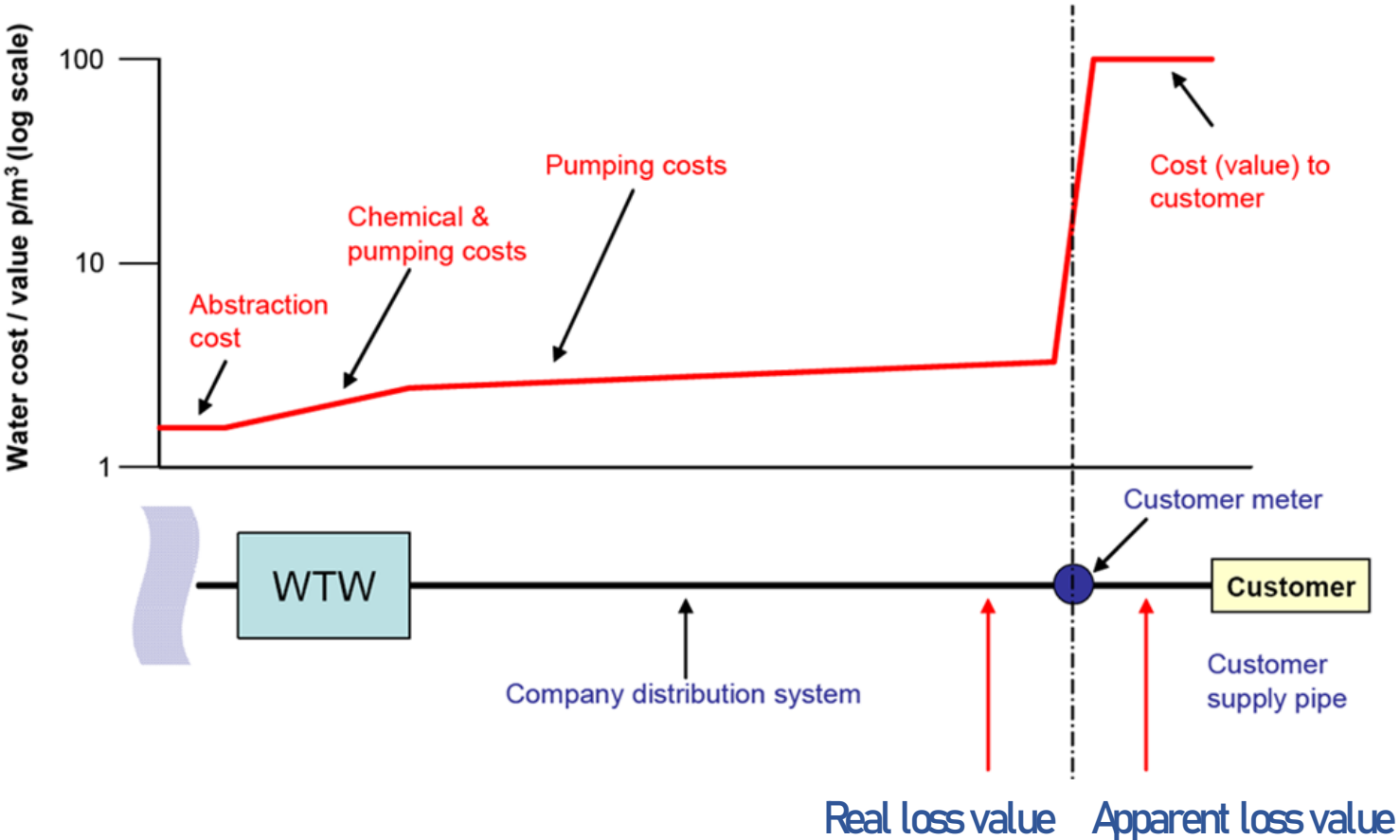
Economic level of water losses (ELWL)



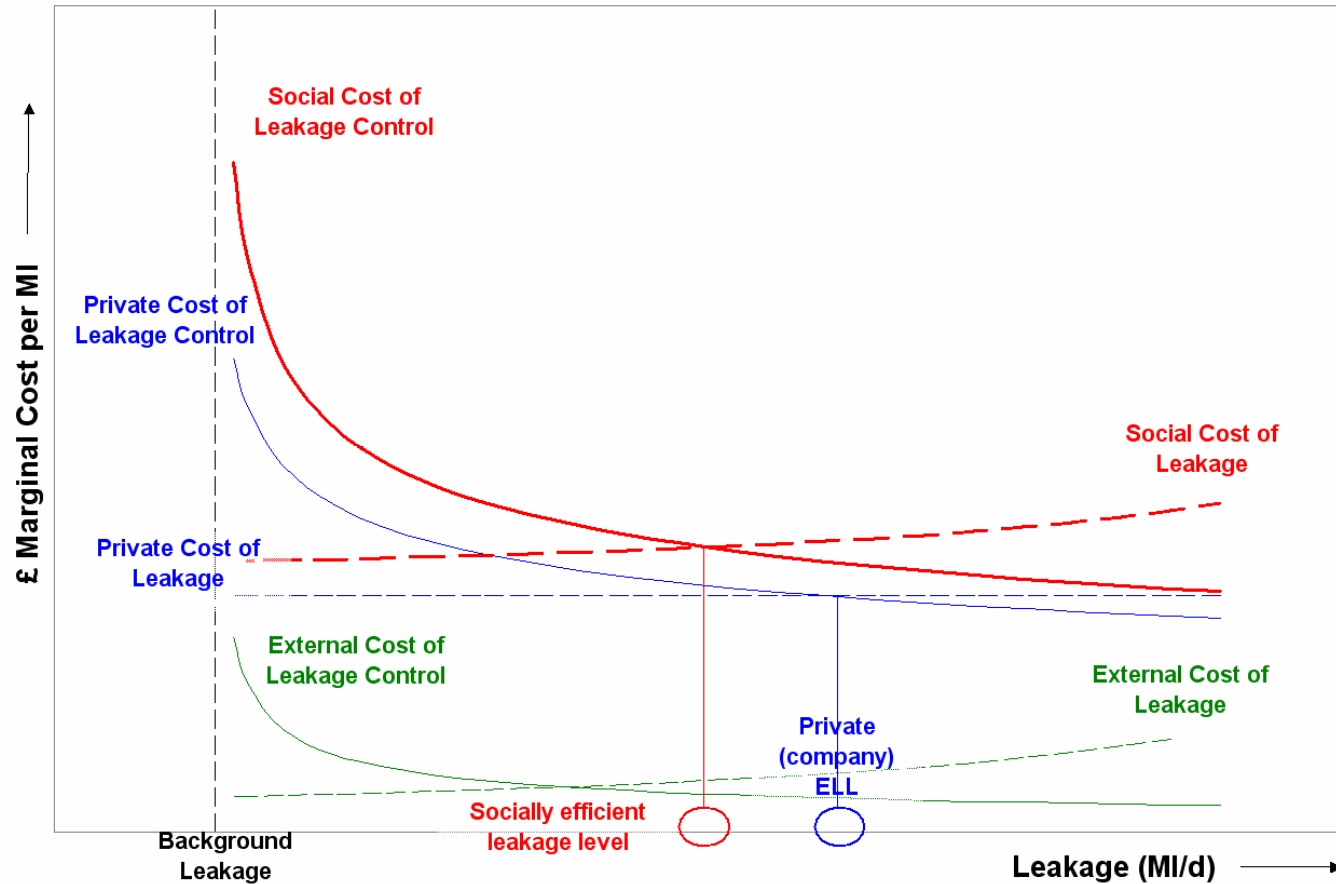
The marginal cost of water



The marginal cost of water

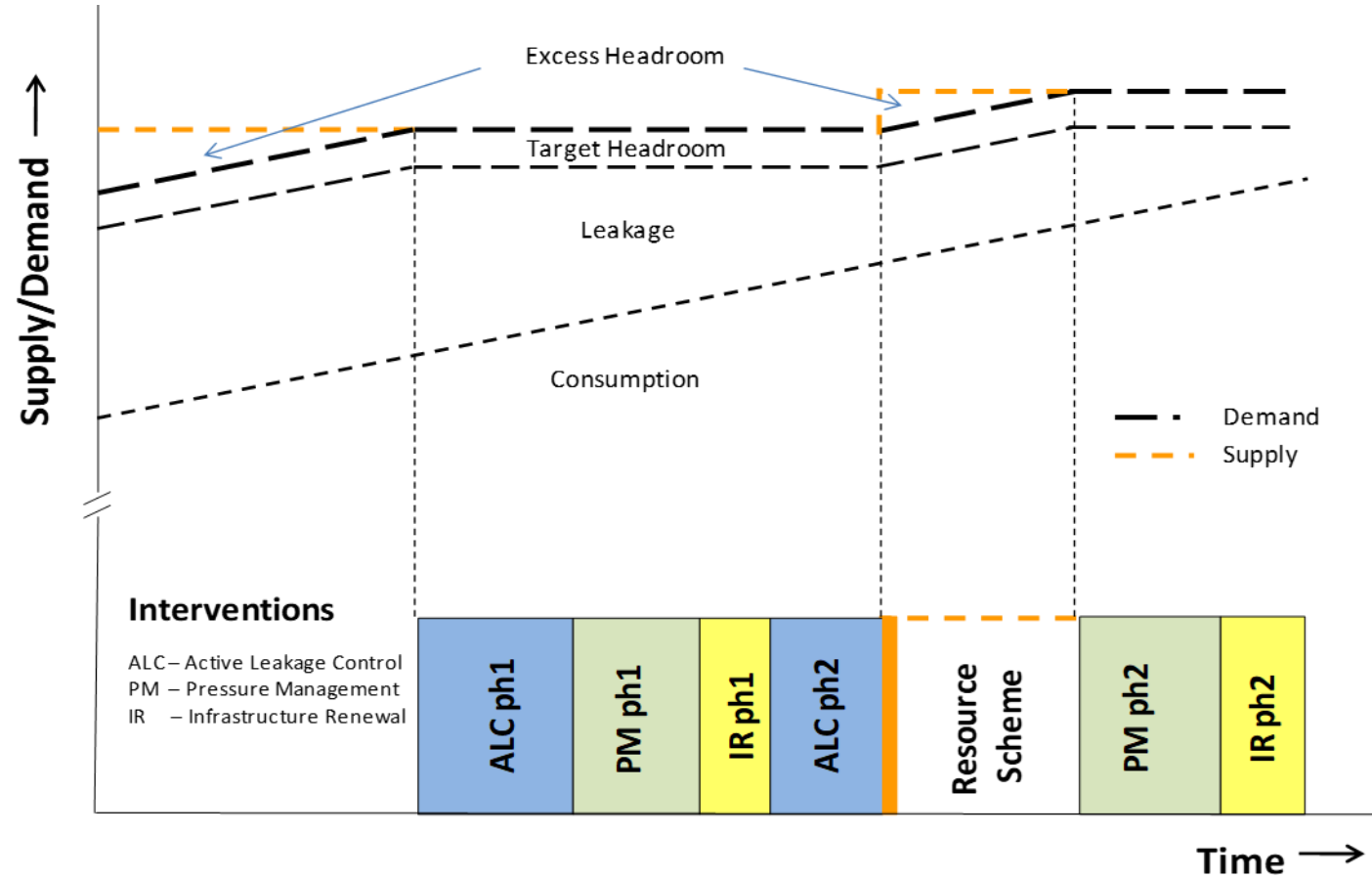


The marginal cost of water

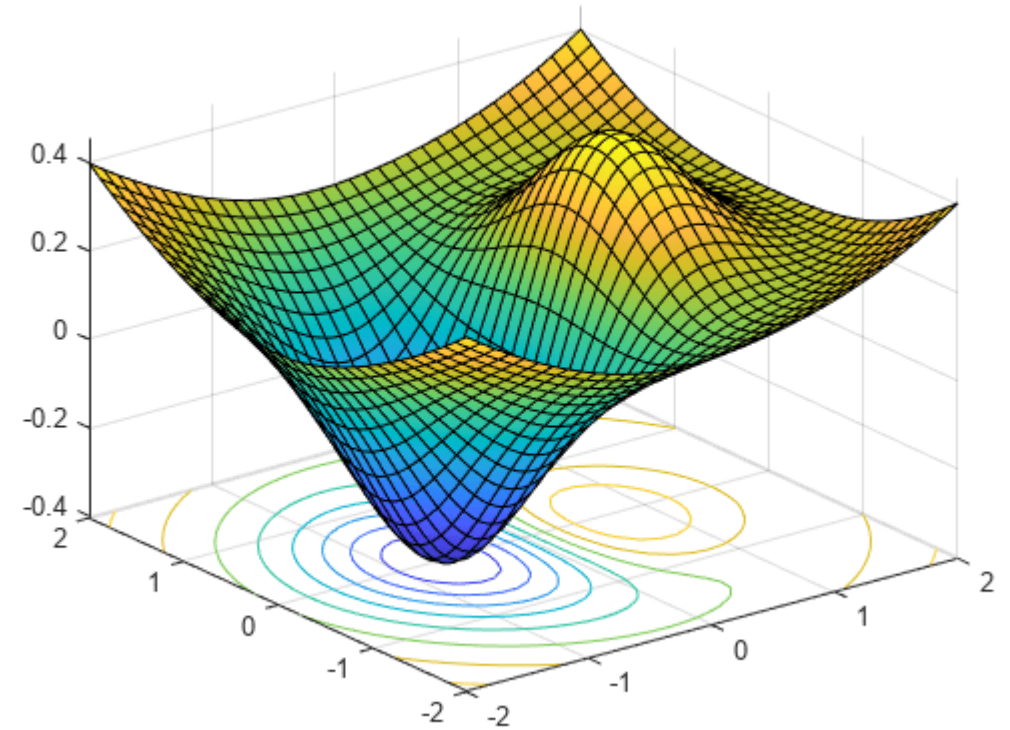
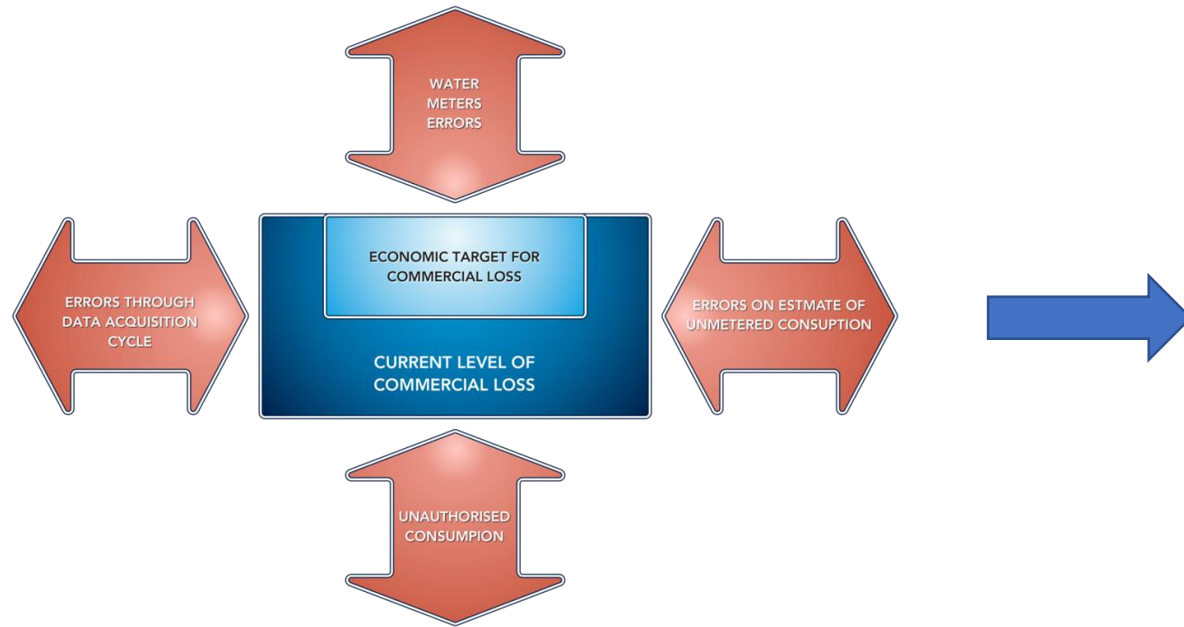


- Social impacts of NRWControl
 - ✓ Road traffic delays/disruption and diversions; Commercial and domestic disruption
- Environmental impacts of NRWControl
 - ✓ changes in abstraction from rivers; groundwater, or reservoirs \Rightarrow loss of environmental services
- Carbon-related impacts of NRWControl
 - ✓ carbon emitted from pumping and related fuel use, and greenhouse gas emissions arising from water treatment

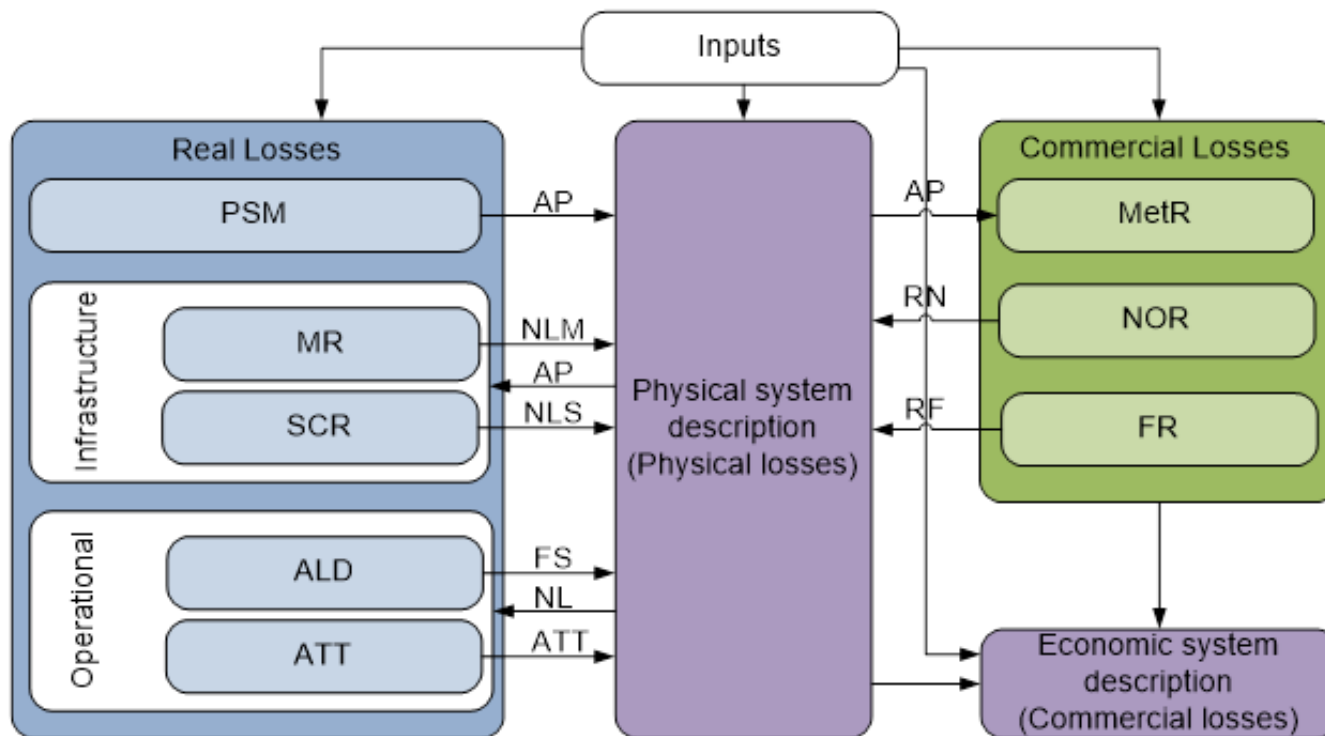
Least cost plan



Least cost plan



Least cost plan optimization model



PSM – Pressure management
 MR – Mains replacement
 SCR – Service connections replacement
 ALD – Active leak detection
 ATT – Attention times
 MetR – Meter replacement
 NOR – Normalization of illegal clients
 FR – Frauds detection

AP – Average Pressure
 NLM – Number of leaks in mains
 NLS – Number of leaks in service connections
 NL – Number of leaks (NLM & NLS)
 FS – Attention time in non-reported leaks (Survey Frequency)
 ATT – Attention time in reported leaks
 RN – Recuperation of physical volume by normalization
 RF – Recuperation of physical volume by Fraud control

Least cost plan optimization model

	System data	Parameters and Historical Data			Calculated Data			
	0	1	2	3	4	5	6	7
ACTIVE LEAKAGE DETECTION								
Time to total survey [yr/surv]	1,47	0,85	0,49	0,50	0,48	0,38	0,38	0,38
Mains Length [Km]	5.083	5.144	5.206	5.268	5.331	5.395	5.460	5.526
Number of conections [con]	731.301	745.227	759.152	773.078	787.003	800.929	814.855	828.780
Number of Non-Reported leaks in Mains [leak]	1.017	767	619	539	670	873	1.093	1.216
Number of Non-Reported leaks in S. Connections [leak]	5.439	6.686	4.731	5.064	8.449	9.178	10.076	10.536
Non Reported Leak Indexes Mains [leak/Km]	0,20	0,15	0,12	0,10	0,13	0,16	0,20	0,22
S. Connection [leak/1000 con]	7,44	8,97	6,23	6,55	10,74	11,46	12,37	12,71
Non-Reported leak flow in Mains @ 50 mcw [m ³ /h]	6,00	5,99	5,81	5,82	5,80	5,56	5,56	5,56
Non-Reported leak flow in S. Connections [m ³ /h]	0,53	0,53	0,52	0,52	0,51	0,49	0,49	0,49
Marginal Cost of Water [\$R/m ³]	0,24	0,24	0,24	0,24	0,24	0,24	0,24	0,24
Inspection cost ALD [\$R/km]	494,00							
Mains leak repair cost [\$R/leak]	550,14							
S. Connection leak repair cost [\$R/leak]	239,62							
Average Pressure [mcw]	45,00	45,00	45,00	44,95	44,93	44,93	44,92	44,91
Pressure-Flow coefficient (N1)	1,15							
Technology Number for ALD	1							
Leak Time [yr]	0,66	0,42	0,25	0,25	0,24	0,19	0,19	0,19
Survey Cost [\$R]	1.707.481,36	2.998.538,15	5.220.404,09	5.204.974,33	5.478.131,38	7.009.795,84	7.093.913,39	7.179.040,36
Time to total survey [yr/surv]	1,47	0,85	0,49	0,50	0,48	0,38	0,38	0,38

Least cost plan optimization model

FRAUD MANAGEMENT	System data	Parameters and Historical Data			Calculated Data			
	0	1	2	3	4	5	6	7
Number of visits	5413	7671	12048	15572	19723	22370	22000	22000
Average consumption in Fraudulent Client [m ³ /month]	39							
Average consumption regular client [m ³ /month]	13,8							
Average water sell price [\$/m ³]	9,252	9,252	9,252	9,252	9,252	9,252	9,252	9,252
Average cost of simple Inspection [\$/R]	60							
Cost of Inspection with Digging [\$/R]	150							
Efficiency of simple Inspection	0,3							
Efficiency of Inspection with Digging	0,85							
Percentage of Digging in Inspections	0,2							
Number of simple Inspections	4330,4	6136,8	9638,4	12457,6	15778,4	17896	17600	17600
Number of Inspections with Digging	1082,6	1534,2	2409,6	3114,4	3944,6	4474	4400	4400
Number of potential Fraudulent Clients	5829	3901	1118	125	14	2	0	0
Number of fraudulent clients inspected	2219,33	3145,11	1117,696874	125,1820498	14,02038958	1,570283633	0,175871767	0,019697638
Average duration of Fraud [month]	12							
Number of Frauds found without Digging	1299,12	1841,04	894,1574989	100,1456399	11,21631167	1,256226907	0,140697414	0,01575811
Number of Frauds found with Digging	920,21	1304,07	223,5393747	25,03640997	2,804077917	0,314056727	0,035174353	0,003939528
Reincidents	221,933	314,511	111,7696874	12,51820498	1,402038958	0,157028363	0,017587177	0,001969764
Volume of recovered water as Real Loss [m ³ /year]	670.162	1.552.861	1.795.396	1.799.446	1.799.899	1.799.950	1.799.956	1.799.956
Volume of Billed Water [m ³ /year]	368.485	853.832	987.189	989.416	989.665	989.693	989.696	989.696
Cost of recovered water [\$/R]	3.570.060	8.272.343	9.564.364	9.585.940	9.588.356	9.588.627	9.588.657	9.588.660
Fee per detected fraud [\$/fraud]	437911,7	620583,9	198950,0435	22282,40487	2495,629346	279,5104867	31,30517451	3,506179545
Total cost of Fraud Detection [\$/fraud]	-15697,7	-22245,9	740793,9565	1192333,595	1535898,371	1744580,49	1715968,695	1715996,494
Social and Environmental Cost [\$/R]	67016,16543	155286,0998	179539,5625	179944,5699	179989,9307	179995,0112	179995,5802	179995,6439
Total Cost [\$/R]	-4090685,599	-9070458,776	-9202059,896	-8595833,029	-8234943,284	-8024320,768	-8052715,239	-8052663,099

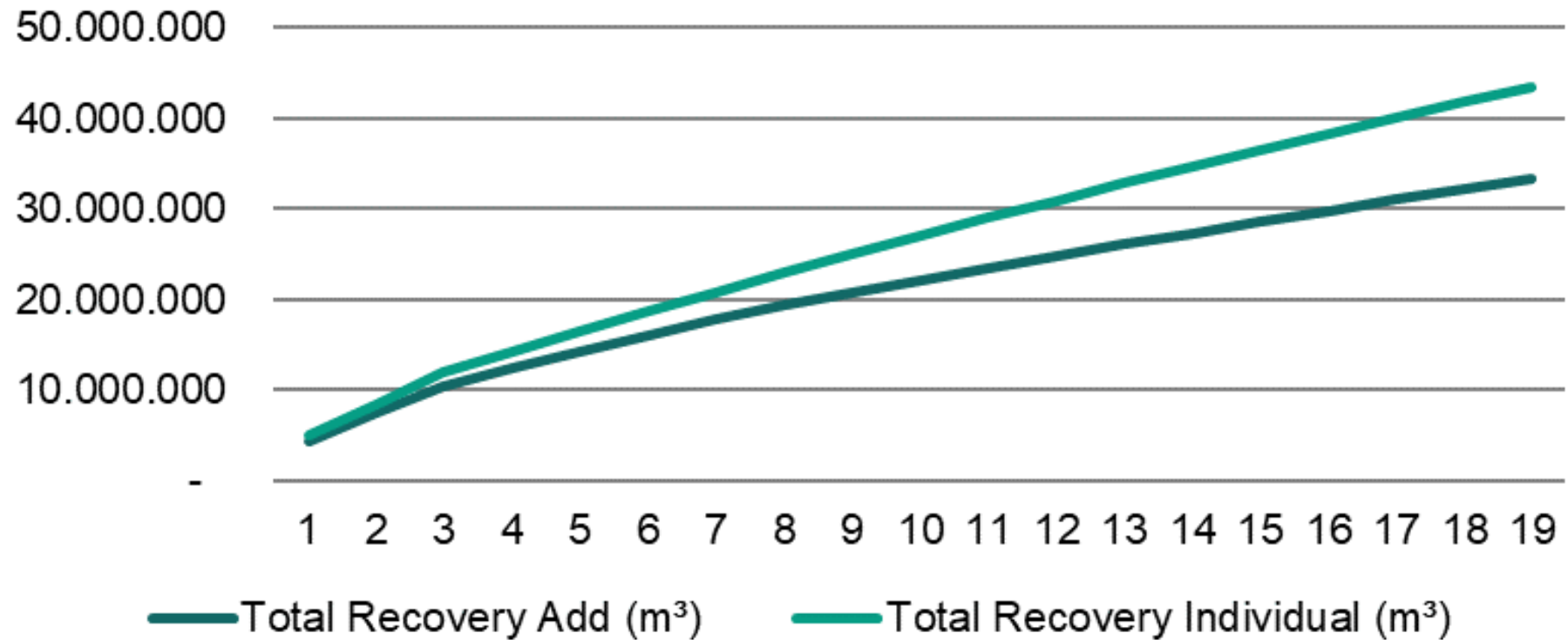
Least cost plan optimization model

07 Medidores prepago									
VPN									
(\$ 892.195.007)									
(\$ 1.767.327.826)									
Año	0	1	2	3	4	5	6	7	8
Costo de Inversión	962.500.000	962.500.000	962.500.000	962.500.000	539.000.000	962.500.000	731.500.000	-	962.500.000
Costo operacional	-	-	-	-	-	-	-	-	-
Costo del agua recuperada	474.900.000	532.980.000	596.736.000	666.590.400	529.031.009	796.775.426	767.980.555	469.543.783	993.130.619
Volumen recuperado	750.000	1.080.000	1.410.000	1.740.000	1.740.000	2.254.800	2.404.800	2.085.600	2.835.600
Flujo de Caja	487.600.000	429.520.000	365.764.000	295.909.600	9.968.991	165.724.574	(36.480.555)	(469.543.783)	(30.630.619)
Costos Sociales y ambientales	(91.460.000)	(95.420.000)	(99.380.000)	(103.340.000)	(67.057.600)	(109.517.600)	(91.527.200)	(25.027.200)	(116.487.200)
Sub-Total	396.140.000	334.100.000	266.384.000	192.569.600	(57.088.609)	56.206.974	(128.007.755)	(494.570.983)	(147.117.819)
08 Control de fraudes									
VPN									
(\$ 72.724.225.240)									
(\$ 73.415.622.709)									
Año	0	1	2	3	4	5	6	7	8
Costo de Inversión	-	-	-	-	-	-	-	-	-
Costo operacional	207.522.000	207.522.000	207.522.000	207.522.000	207.522.000	207.522.000	207.522.000	207.522.000	207.522.000
Costo del agua recuperada	1.377.493.506	2.511.327.618	3.645.161.730	4.778.995.842	5.912.829.954	7.046.664.066	8.180.498.178	9.314.332.290	10.448.166.402
Volumen recuperado	451.008	902.016	1.353.024	1.804.032	2.255.040	2.706.048	3.157.056	3.608.064	4.059.072
Flujo de Caja	(1.169.971.506)	(2.303.805.618)	(3.437.639.730)	(4.571.473.842)	(5.705.307.954)	(6.839.142.066)	(7.972.976.178)	(9.106.810.290)	(10.240.644.402)
Costos Sociales y ambientales	(77.628.910)	(78.037.819)	(78.446.729)	(78.855.638)	(79.264.548)	(79.673.458)	(80.082.367)	(80.491.277)	(80.900.186)
Sub-Total	(1.247.600.416)	(2.381.843.437)	(3.516.086.459)	(4.650.329.480)	(5.784.572.502)	(6.918.815.524)	(8.053.058.545)	(9.187.301.567)	(10.321.544.588)
09 Legalización de Subnormales									
VPN									
\$ 611.774.534									
(\$ 309.868.681)									
Año	0	1	2	3	4	5	6	7	8
Costo de Inversión	240.000.000	240.000.000	150.000.000	210.000.000	180.000.000	120.000.000	150.000.000	210.000.000	-
Costo operacional	-	-	-	-	-	-	-	-	-
Costo del agua recuperada	13.687.120	30.860.960	40.505.010	54.006.680	65.579.540	73.294.780	82.938.830	96.440.500	96.440.500
Volumen recuperado	28.000	77.792	102.102	136.136	165.308	184.756	209.066	243.100	243.100
Flujo de Caja	226.312.880	209.139.040	109.494.990	155.993.320	114.420.460	46.705.220	67.061.170	113.559.500	(96.440.500)
Costos Sociales y ambientales	(176.205.248)	(176.672.000)	(110.882.000)	(155.176.000)	(133.428.000)	(89.596.000)	(111.806.000)	(156.100.000)	(2.100.000)
Sub-Total	50.107.632	32.467.040	(1.387.010)	817.320	(19.007.540)	(42.890.780)	(44.744.830)	(42.540.500)	(98.540.500)
Flujo de Caja Total	17.544.741.207	11.257.633.631	4.826.557.915	(1.500.347.757)	(7.404.621.952)	(13.104.877.263)	(19.248.316.632)	(24.465.123.419)	(28.424.789.020)
VPN Proyecto sin costos A&S @20	(\$ 114.225.003.991)								
VPN Proyecto sin costos A&S @10	(\$ 40.485.529.010)								
VPN Proyecto sin costos A&S @5	\$ 18.030.883.977								
Total	17.155.065.145	10.863.121.908	4.490.840.458	(1.884.969.099)	(7.731.862.527)	(13.431.395.028)	(19.579.702.532)	(24.774.950.968)	(28.672.723.074)
VPN Proyecto con costos A&S	(\$ 112.128.622.131)								
	(\$ 42.773.889.017)								
	\$ 16.337.429.496								
Disponibilidad de presupuesto									
Total	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000	28.000.000.000

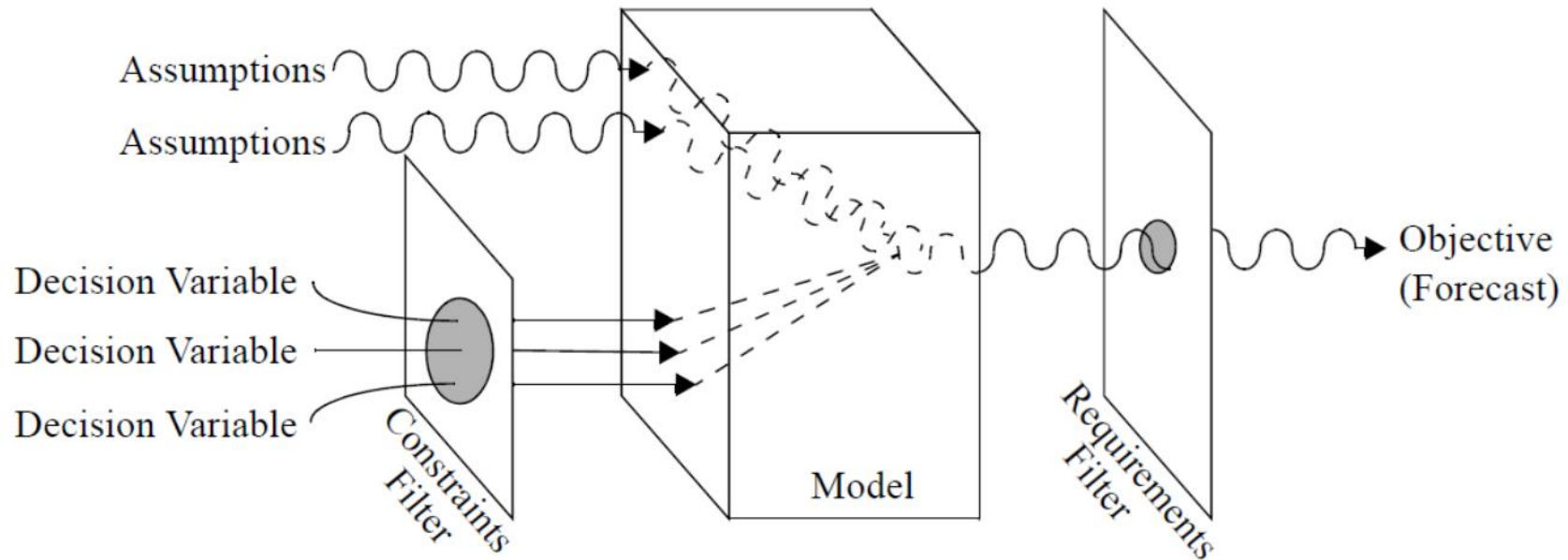
Objective: Minimize cash flow NPV

Restrictions: Yearly allocated budget, Utility operational capacity, Restricted labor hiring

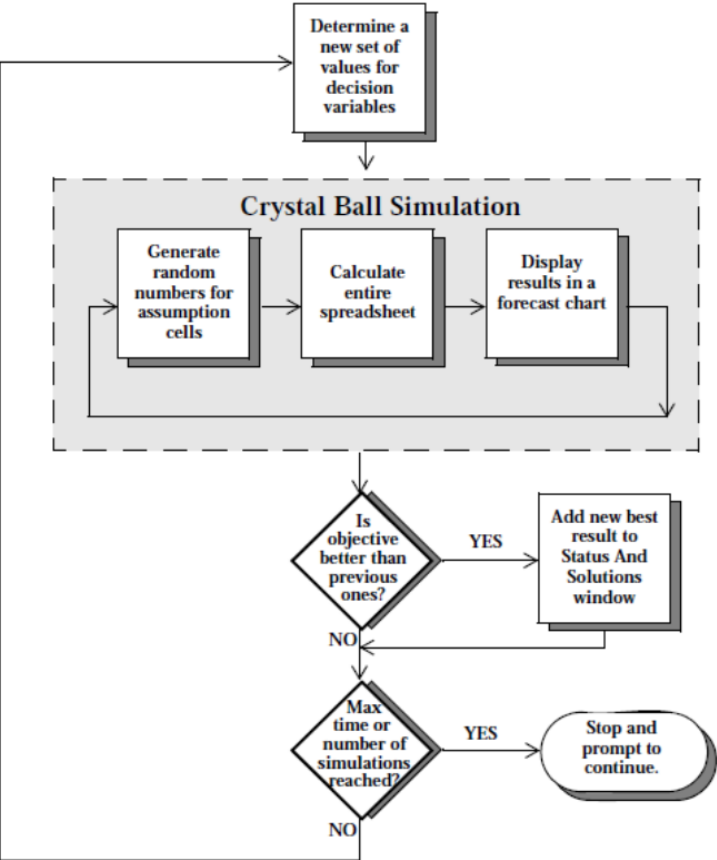
NRW Glide-path



Uncertainty analysis



Montecarlo simulation



OptQuest Results

14 Iterations

Best Solution View

Performance Chart

Y-axis: VPN Proyecto con costos A&S @20 (ranging from \$55,815,122.016 to \$55,815,122.034)

X-axis: Iterations (0 to 10)

Legend: Best solution (green line), Infeasible (red dotted line), Last best (green diamond)

Control Panel - OptQuest

Running optimization... Deterministic

Time (min:sec): 00:26 / 25:00:00

Trials 1 / 1

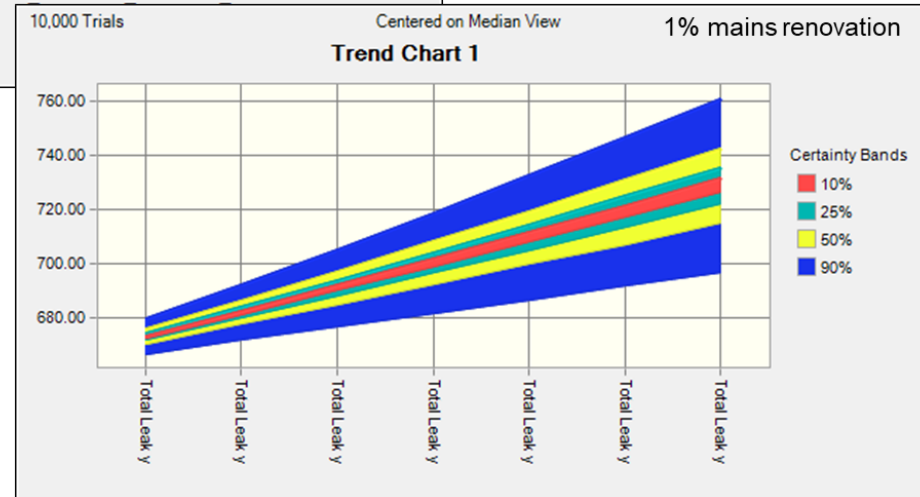
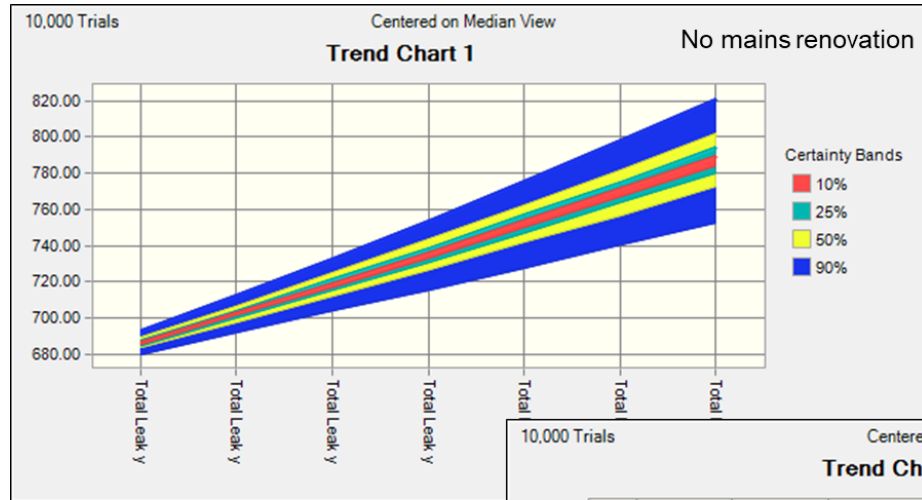
Statistics

Run statistics:	
Total optimization time (min: sec)	00:26
Number of iterations	15
Seconds/iteration (average)	2
Other statistics:	
Number of infeasible solutions	14
Due to requirements	14
Due to non-linear constraints	0
Iterations since last new best solution	14

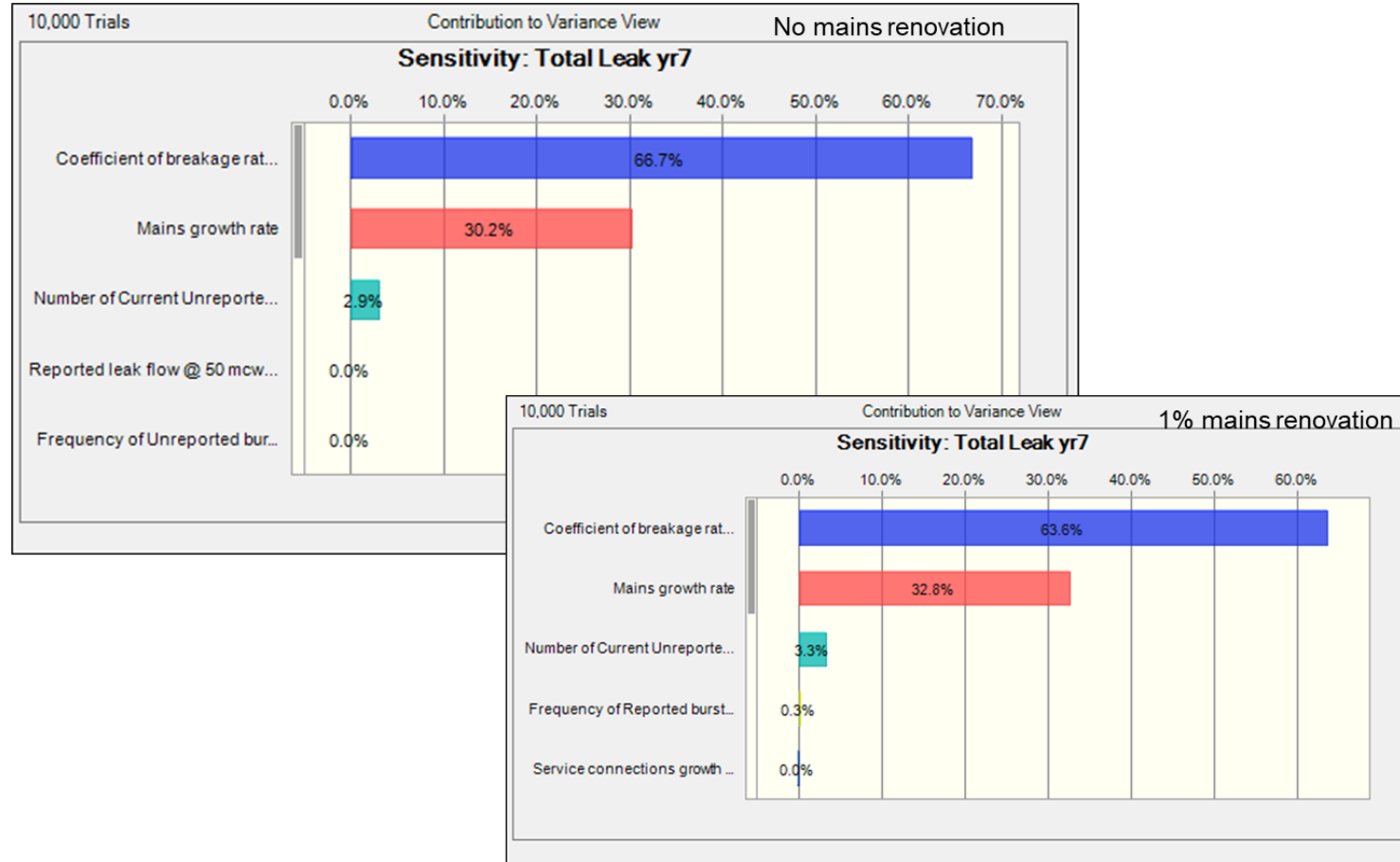
Best Solution:

Objectives	Value
Minimize the Final Value of VPN Proyecto con costos A&S @20	\$
Requirements	
Constraints	
Decision Variables	Value
01 00	
01 01	
01 02	

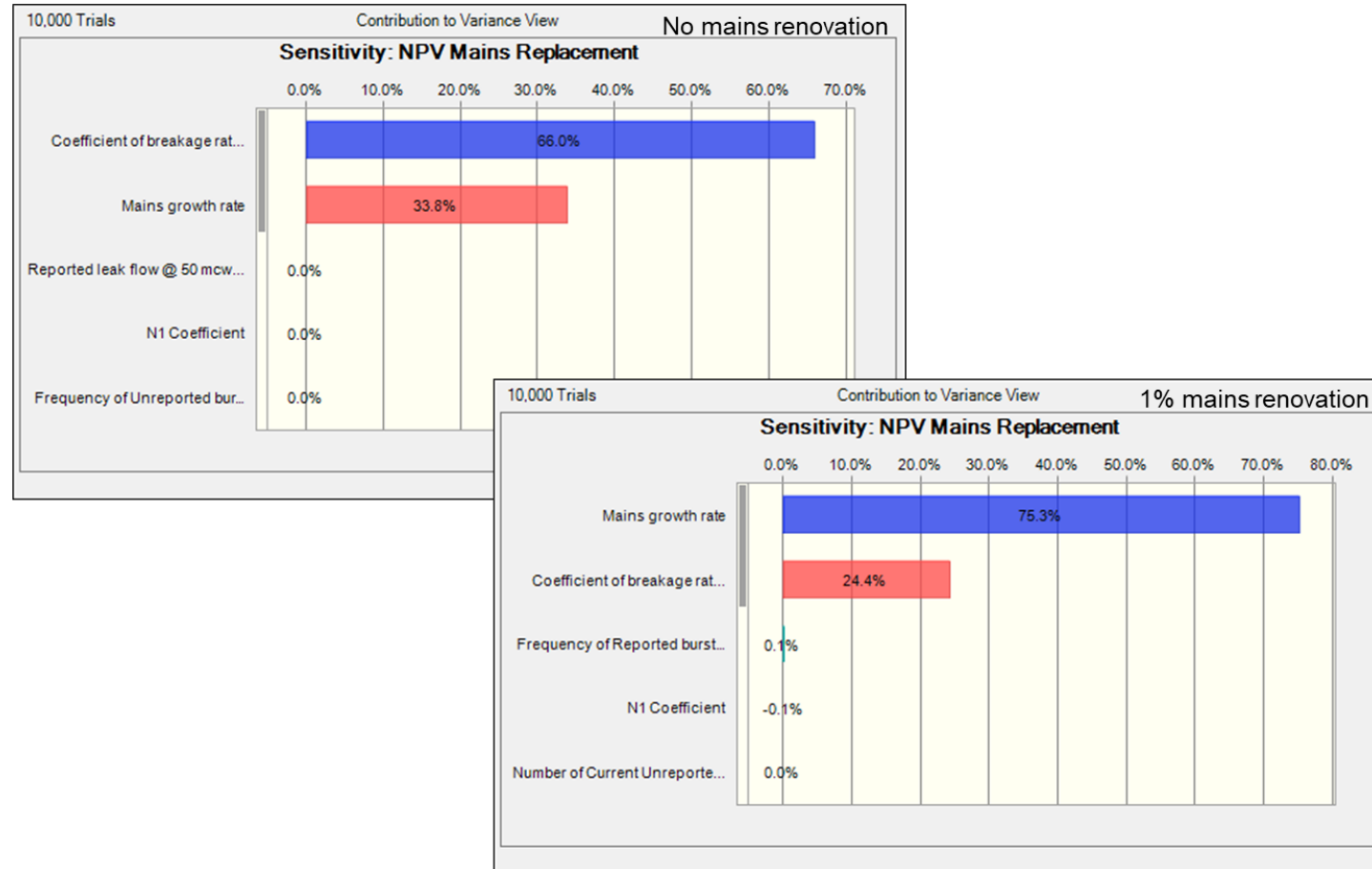
Uncertainty analysis



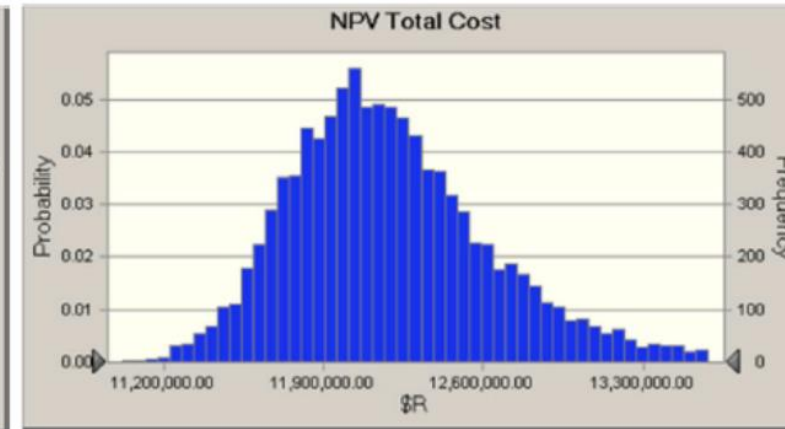
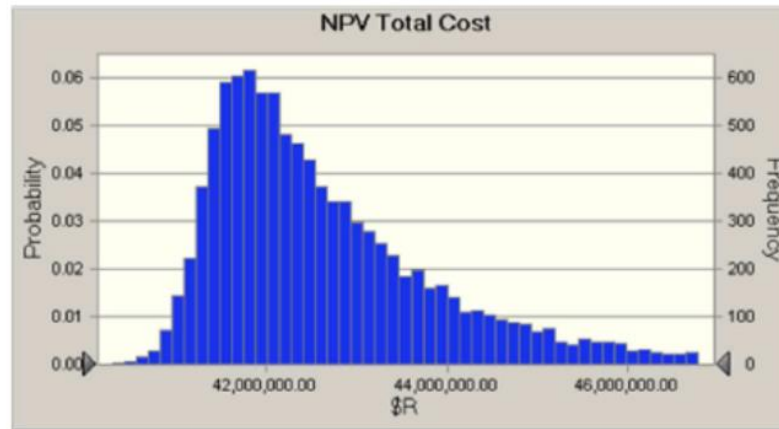
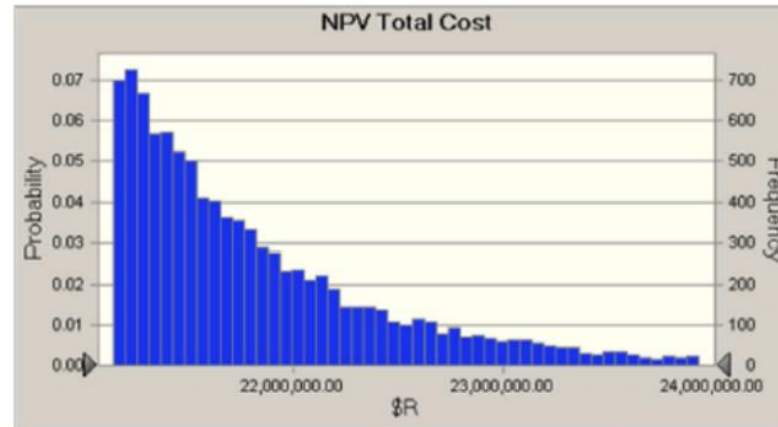
Sensitivity analysis



Sensitivity analysis



Sensitivity analysis





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