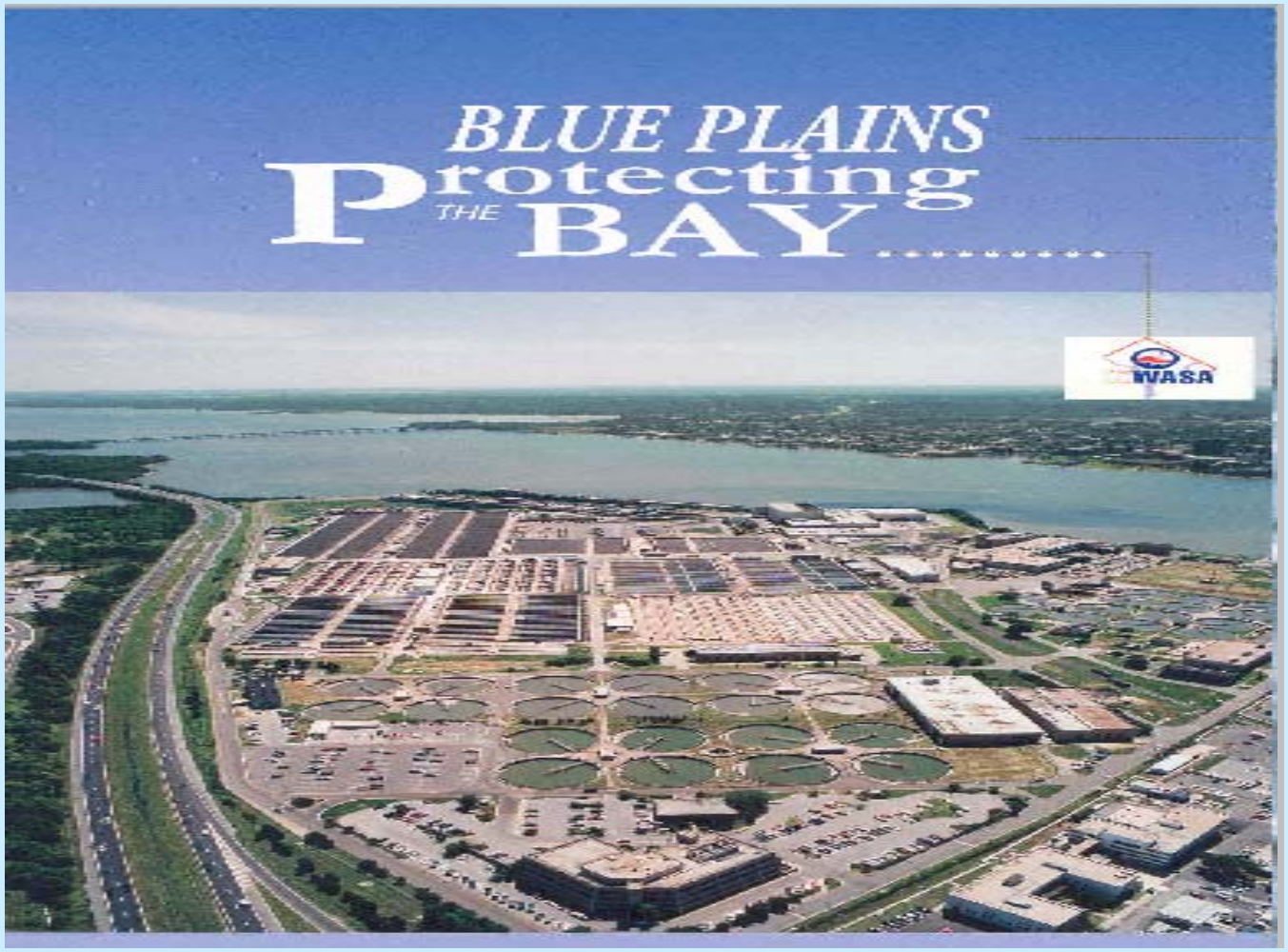
Decision for DCWASA

"SELECT CHEMICALS TO IMPROVE WASTEWATER TREATMENT PROCESS"



Overview

- DCWASA, District of Columbia Water and Sewer Authority, is the largest wastewater treatment plant in the world.
- Wastewater is treated from MD, VA, and DC.
- DCWASA serves more than two million people and the average flow to the plant is 370 million gallons per day.

Overview

- Nitrification and Denitrification process
  - These processes reduce the amount of nitrogen in wastewater, which will be discharged to Potomac river.

Denitrification demonstration reactors and sedimentation basins at the Blue Plains Facility are outlined in orange. The control train is outlined in blue.

Overview

- Nitrification and Denitrification process
  - -However, the nitrification and denitrification processes change the wastewater alkalinity.
  - -To maintain a target residual alkalinity of 80 mg/l as CaCO3, supplemental alkalinity addition to the nitrification process is required
  - -From 1981-2001, additional alkalinity for the process at DCWASA was provided by lime.

Overview

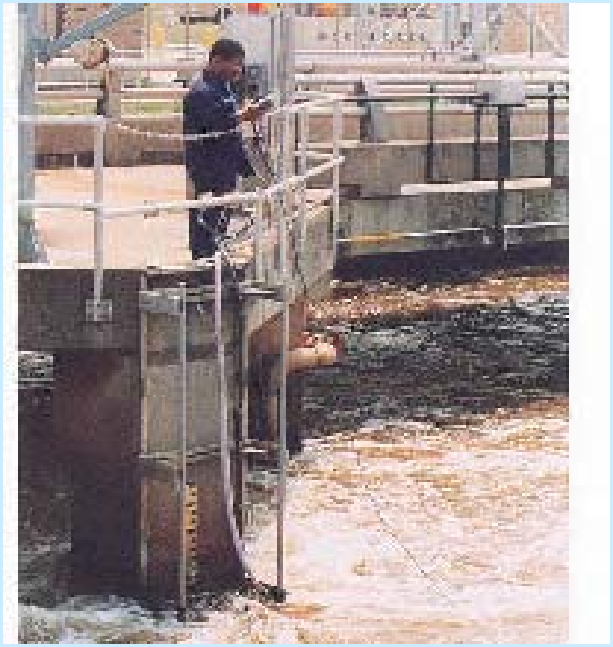
- For years, the lime storage and feed facilities have experienced repeated failures and require nearly continual maintenance
- In addition, the lime facilities created additional plant maintenance issues according to migration of lime dust.
- As the result, DCWASA decided to construct the temporary Sodium Hydroxide Facilities in 2000.

Overview

•This facility satisfies the alkalinity needs of the nitrification process.
•However, costs for sodium hydroxide are high, especially compared to lime, and are wide variation because sodium hydroxide is produced as a byproduct of production of chlorine based compounds.
•Also, sodium hydroxide is a very hazardous chemical which can effect to those who work in facility and around facility.

Objective

- Select 1) the chemical and 2) the alternative for the nitrification and denitrification process according to
  1.safety
  2.cost
  3.store and maintenance
  4.effect to process



Select chemicals

Given DCWASA's past history with lime and sodium hydroxide, as part of the preliminary design of the nitrification f acilities, these chemicals were evaluated for use in providing supplemental alkalinity.

1. Lime (CAO)
2. Sodium hydroxide (NaOH, Caustic soda)
3. Potassium hydroxide (KOH)
4. Magnesium hydroxide (Mg(OH)2)
5. Sodium carbonate (Soda ash)

Select chemicals

Subjective rating chemicals

From the given information, we ask the administrator and his team to order this chemicals based on these aspects

1. safety
2. cost
3. store and maintenance
4. effect to process

Select chemicals

	1. Magnesium hydroxide	2. Potasium hydroxide	3.Soda ash	4.Hydrated lime	5.NaOH
	much less harzard to handle when	hazard as NaOH			require a lot of safety measures
safety	compared with NaOH and KOH				for safe handling and storage
					more harzardous than lime
cost	comparatively high	weight 40% greater than NaOH	2 times as much as lime to change	less expensive than other	more expensive than lime
	required the installation of an entirely new	so 40% more KOH is required to provide	the same alkalinity	chemicals considered	cost is variable
	chemical feed facility	the same alkalinity adjustment	high chemical cost compared to lime		
		same price as NaOH			
store and	easy to ship and store but	can be store and fed from the existing	installation of a new chemical storage	difficult and maintenance-intensive	easier to maintain than lime
maintenance	can form deposite in pipelines and valves,	NaOH facilities	and feed system would be required	to handle	facilities
	increasing maintenance requirments		must be stored and pumped at temperature greater than 100 F		
	and costs,				
			have potential of foaming due to generation of carbon dioxide		
effect to process				provide a divalent cation may be	MAY negatively impact sludge
				beneficial in terms of sludge	settleability and dewatering
				settleability	
				and dewatering	
PH	maximum ph 9.5	strong base ph.>13.5	the range of 11	range 12.0	>=13.5

Select chemicals

chemical substance	safety	cost	store and maintenance	effect to process
1. Magnesium hydroxide	3	3	2	1
2. Potasium hydroxide	1	1	5	1
3.Soda ash	4	3	2	2
4.Hydrated lime	4	5	1	5
5.NaOH	1	2	5	3

Select chemicals

However, to make this rate more meaningful, the administrator and their experienced team have to rate the different levels in the scale, indicating how much each level is worth relative to other levels.

weight for each attribute	0.2	0.3	0.3	0.2
chemical substance	safety	cost	store and maintenance	effect to process
1. Magnesium hydroxide	50	60	20	0
2. Potasium hydroxide	0	0	100	0
3.Soda ash	70	60	20	30
4.Hydrated lime	70	100	0	100
5.NaOH	0	30	100	50

Select chemicals

Over all Score for each chemical		
1. Magnesium hydroxide	34	
2. Potasium hydroxide	30	
3.Soda ash	44	
4.Hydrated lime	64	
5.NaOH	49	

Find alternatives

1. Operate only the existing NaOH facility
2. Construct the smaller Lime facility and continually operate NaOH facility, "Combined facilities"

Find alternatives

•For the two chemicals we selected, Lime and NaOH, a more detailed evaluation war performed.
•We evaluate in terms of the capital, operating, and maintenance costs on the twenty years life cycle basis
•Since the existing sodium hydroxide facilities are new (2001), in good operational order, and have sufficient volume to store sodium hydroxide more than 10 days of average, facilities will not require any capital improvement

Find alternatives

•Compared to Lime facility, the current condition of facilities is out of date, we needs to pay substantial capital for a new facility. Also, using lime facilities to satisfy the alkalanity demand will require a large lime facilities, which would be used infrequently.
•Therefore, using only lime to satisfy the alkalinity demand will not be financially advantage.

Find alternatives

•Another alternative will be considered. The lime facilities will be sized to handle the alkalinity demand that the plant need during a year and the existing sodium hydroxide facilities will be used to satisfy additional demand

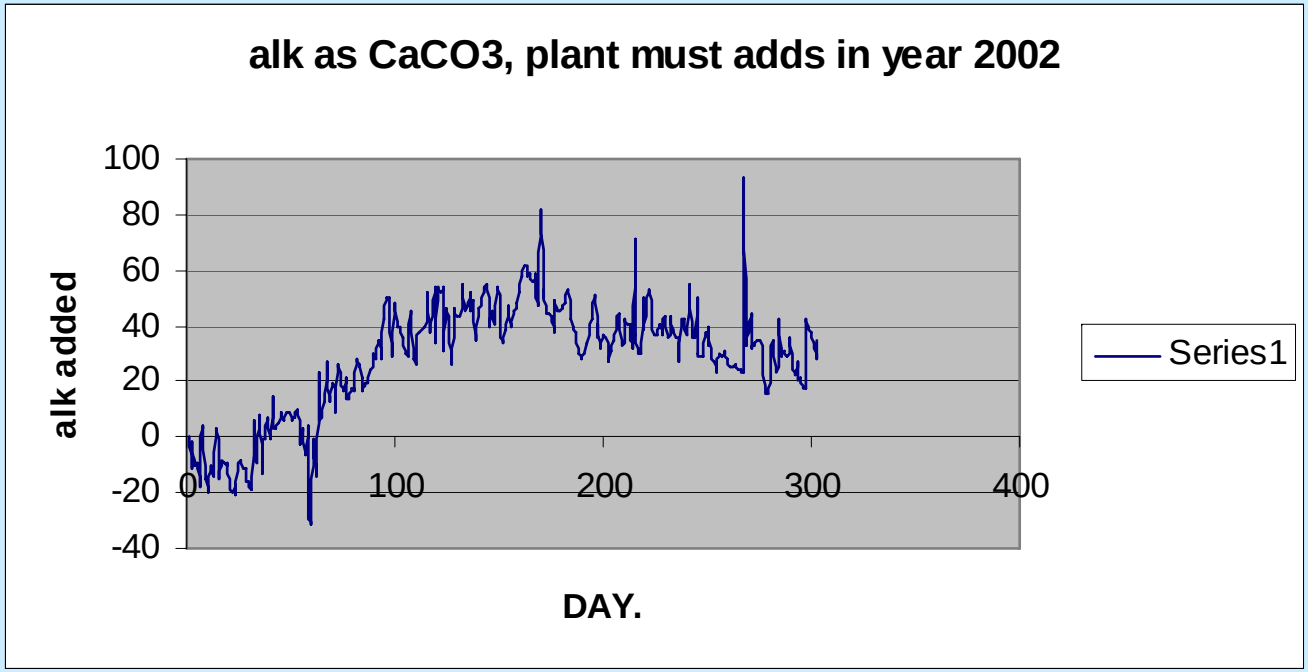
•Therefore, we have two alternatives for making decision

1.Operate only NaOH facility

2.Construct smaller Lime facility and continue using NaOH facility. We will call “Combined facility”

Additional alkalinity year 2002

From the history data, Jan-Oct year 2002, the alkalinity as CaCO3 we need to add to wastewater to maintain the standard alkalinity in wastewater, 80 mg/l is shown below



Additional alkalinity year 2002

- lbs/day as $CaCO_3$= MGD X 8.34 X mg/l $CaCO_3$
- Avg. plant influent=373 million gallon per day

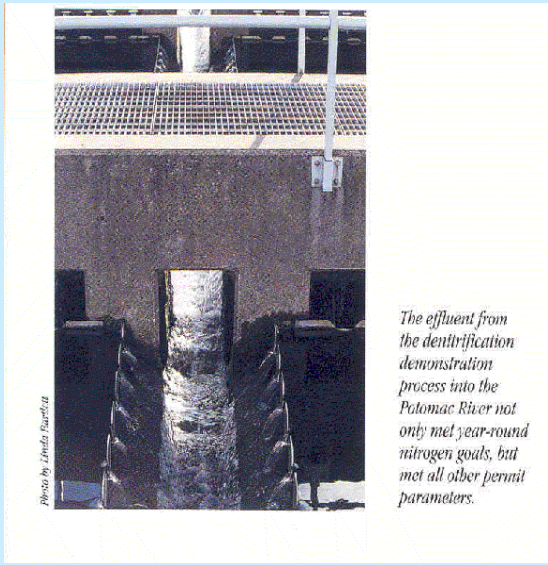
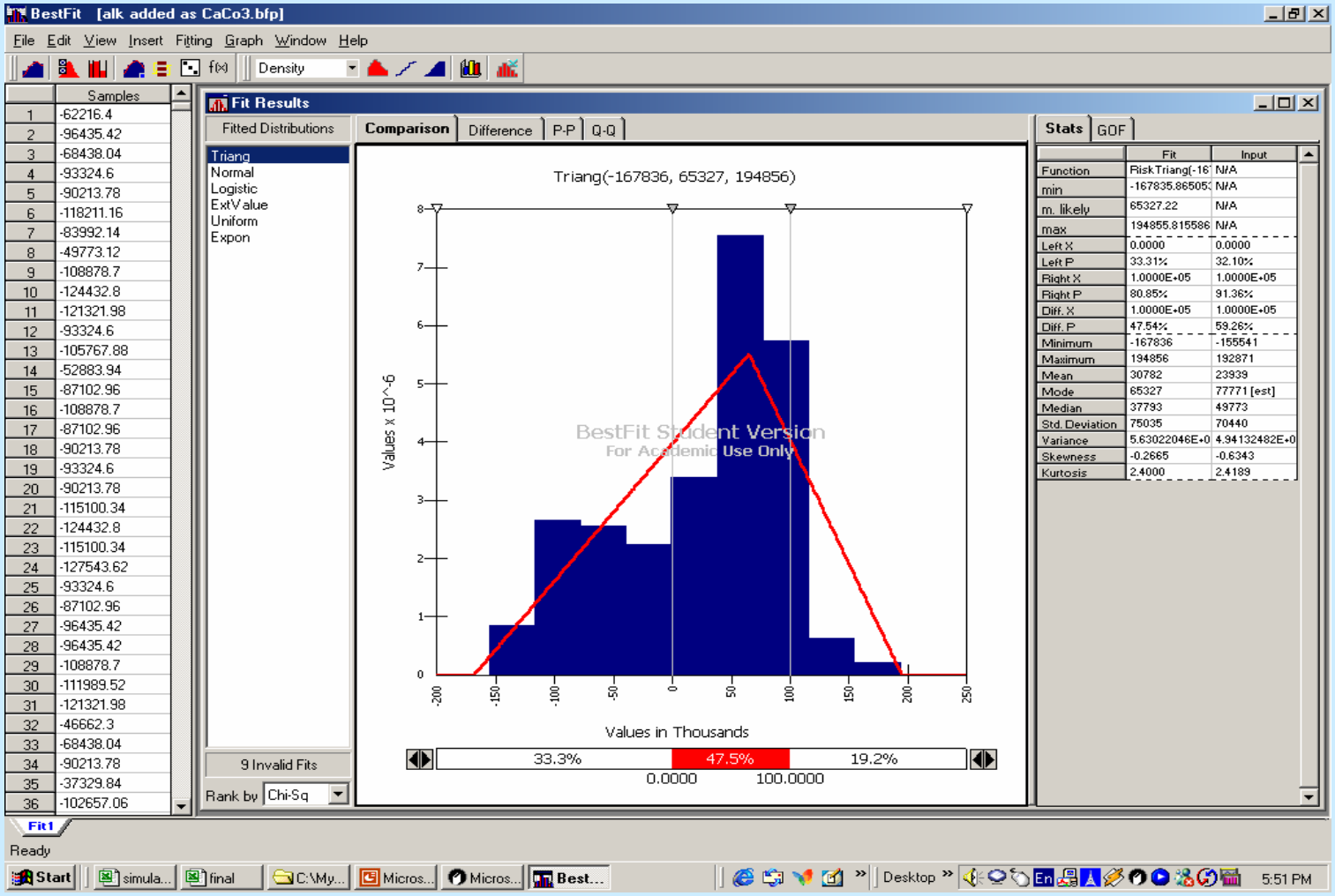


Photo by Linda Fartzia

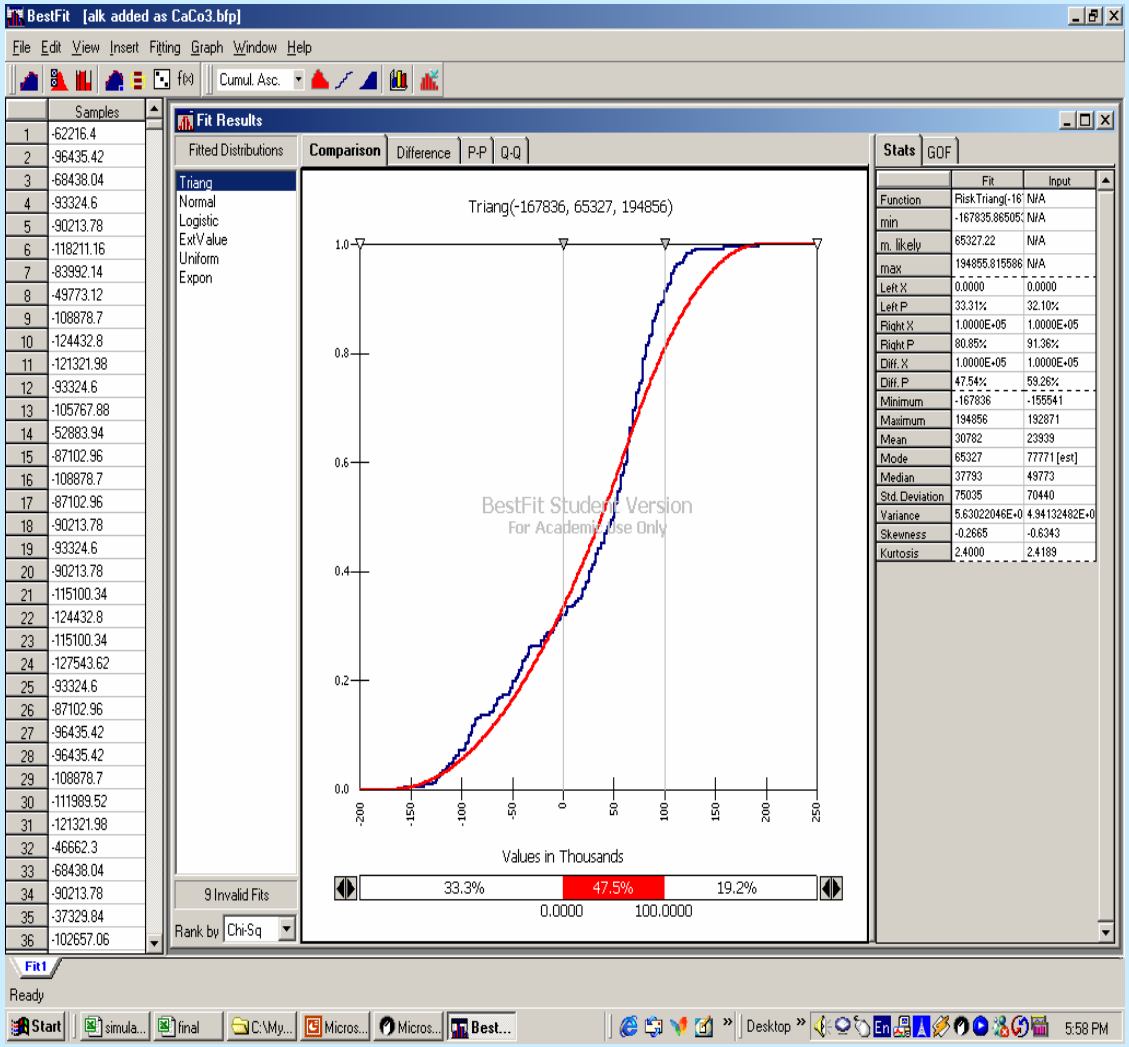
The effluent from the denitrification demonstration process into the Potomac River not only met year-round nitrogen goals, but met all other permit parameters.

Additional alkalinity year 2002

From Bestfit, the distribution of additional alkalinity is in the form of triangular distribution.



Additional alkalinity year 2002

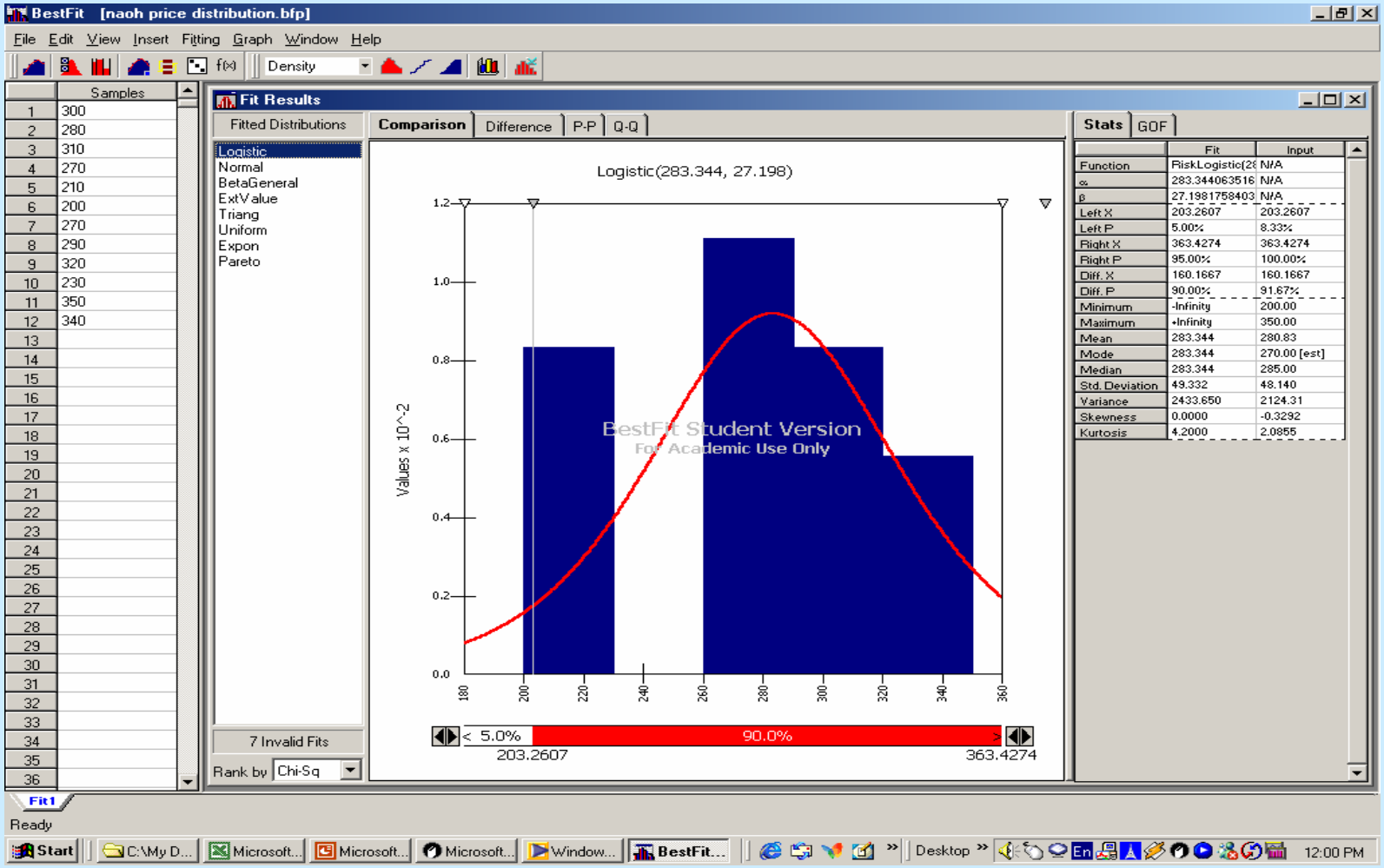


- From cdf, 33% of the year we don't need to add alkalinity
- 66.67% of the year we need to add from
- 0-192871 lbs/day as CaCO3.

Cost of chemical

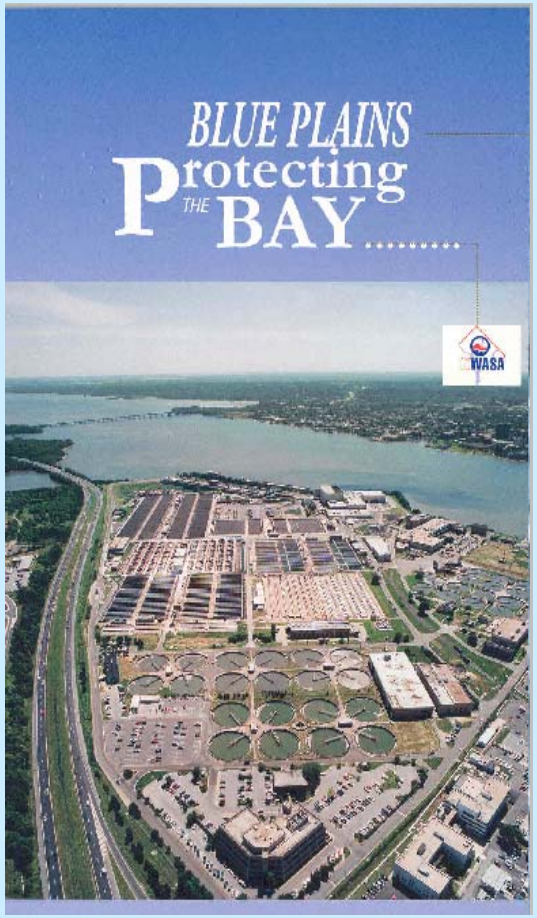
- Lime cost is around $70-$72/ ton, which does not fluctuate much compared to NaOH.
- NaOH price is varied from $0.20-$0.35/kg, based on the historical data we do contract with contractor.

Cost of chemical



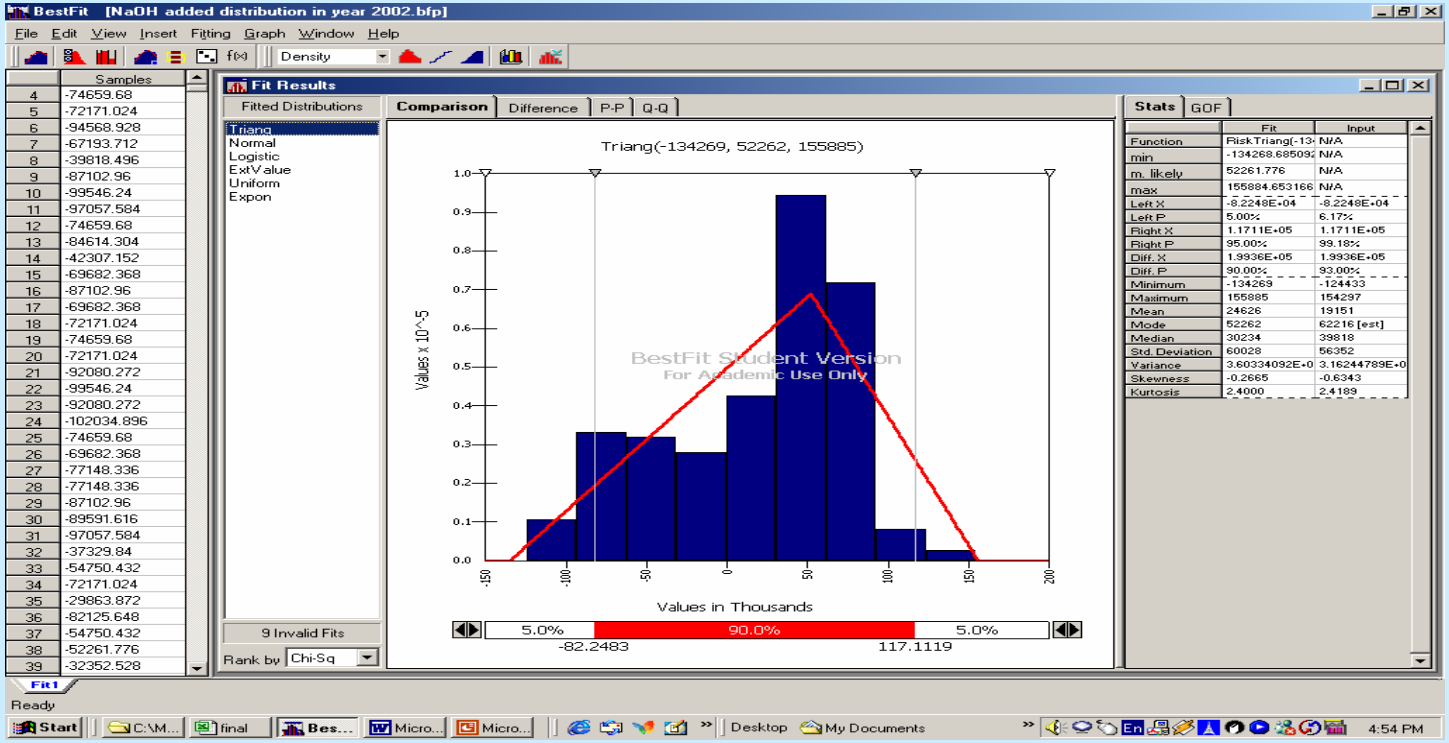
Find overall cost

- NaOH only alternative
- Combined facility alternative

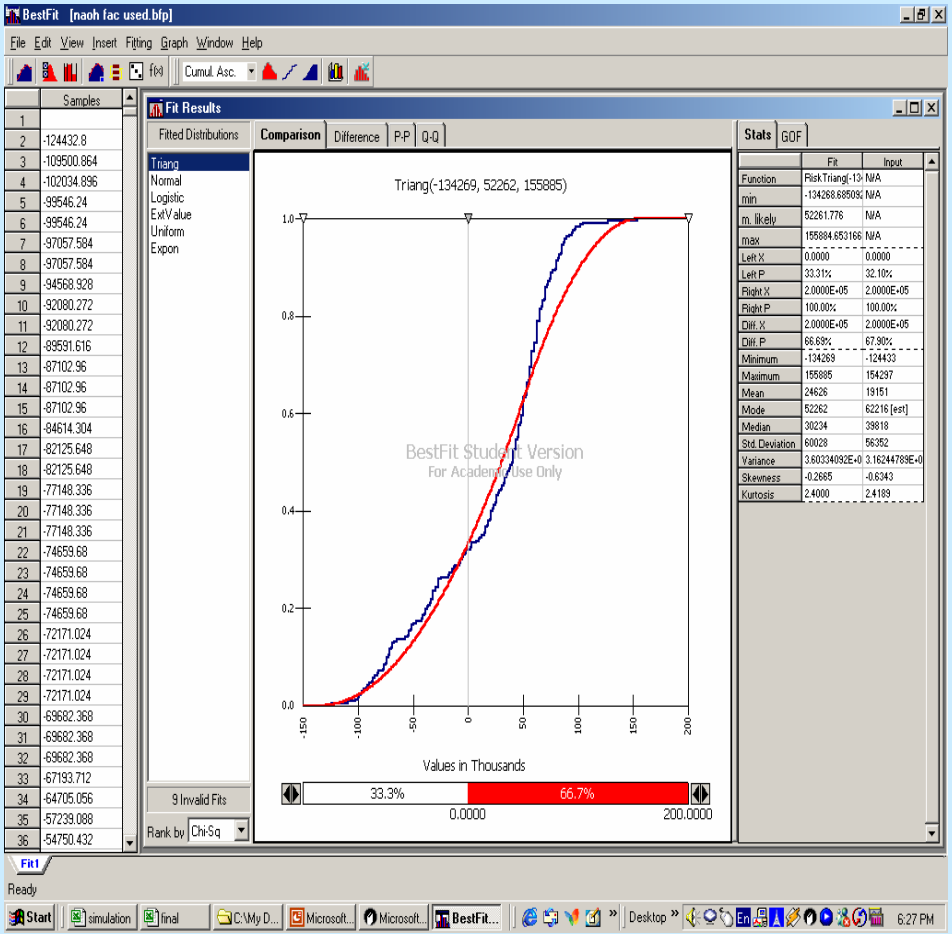


NaOH only facility

- The amount of NaOH used in this facility can calculate by lbs/day as NaOH = lbs/day as CaCO3 X eq.wt. NaOH (40)/eq.wt. CaCO3(50)



NaOH only facility



- We add NaOH 66.67% of year

NaOH only facility

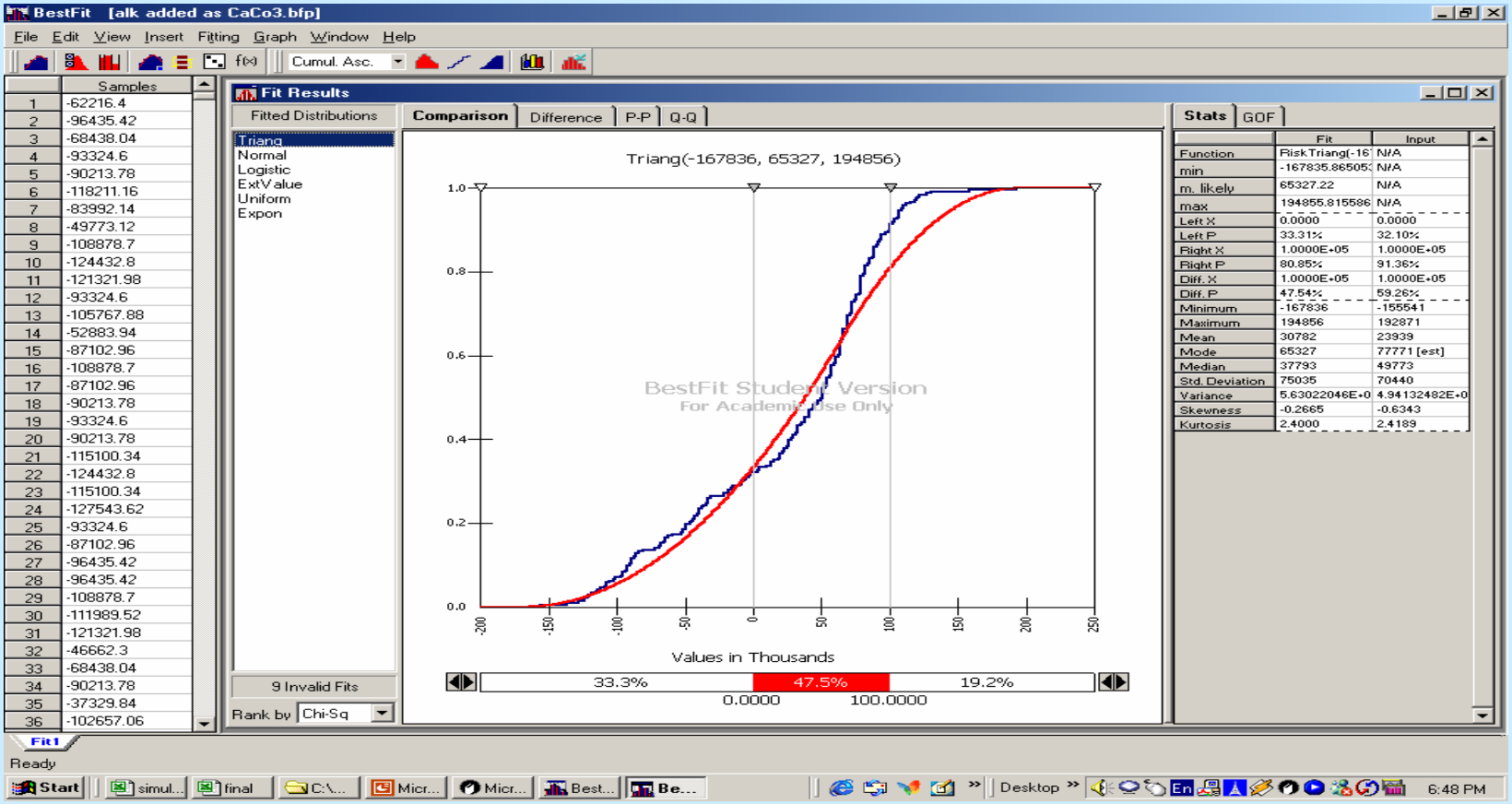
Amount of NaOH used per day						
	lbs/day	ton/day				
most likely	19151	8.675403				
max	154297	69.896541				
min	0	0				
naoh used(lbs/day)	naoh used(t0n)	%naoh used	naoh price(ton)	naoh cost		
19151	8.675403	0.6667	320	675558.5		
1.cost of continued use of the NaOH facility						
cost component	type of cost	cost	present worth 3%*20years		max	min
capital cost	single	-	-			
amount of NaOH used(ton/day)		8.67			69.89	0
price of NaOH(Price/dry ton)		320.00			320	256
annual operation cost for NaOH facilities	annuity	23,432.00	348,609.00	fixed cost	383,469.90	313,748.10
annual maintenance cost for NaOH facilities	annuity	13,320.00	198,168.00	fixed cost	217,984.80	178,351.20
cost of NaOH facility for 20 years	14,049,532.10					

NaOH only facility

- We estimate the cost of operating NaOH facility equaled to $14000000

Combined facility

Construct small lime facility and continue using the existing NaOH facilities



Combined facility

Construct small lime facility and continue using the existing NaOH facilities

From the cdf graph of alk added as CaCO3 year 2002 we can see that

1).33.3% of year we don't need to add any alkalinity

2).47.5% of year we added alkalinity as CaCO3 from 0-100,000 lbs/day

3).19.2% of year we added alkalinity as CaCO3 from 100000-194856 lbs/day

Therefore we decide another alternative for this problem, That is we creat a smaller lime facility by sizing the new lime facility that meets

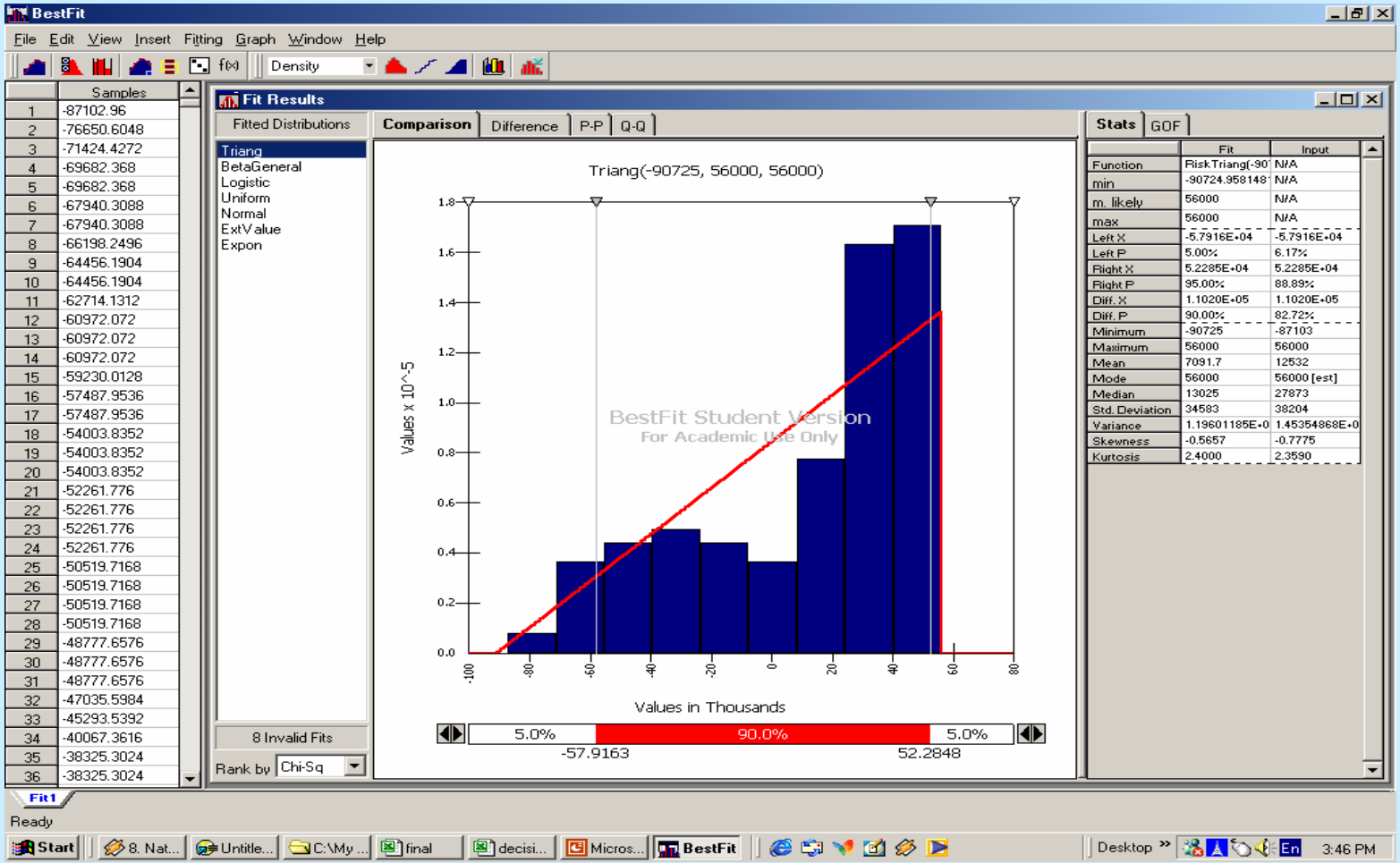
- the 66.67%(47.5%+19.2%) alkalinity as CaCO3 requirement(0-100000lbs/day) and then use the existing NaOH facility when

the alkalinity requirment is over the capacity of this lime facility. That is 19.2% of year.(100000-194856lbs/day)

We call this alternative "combined facility"

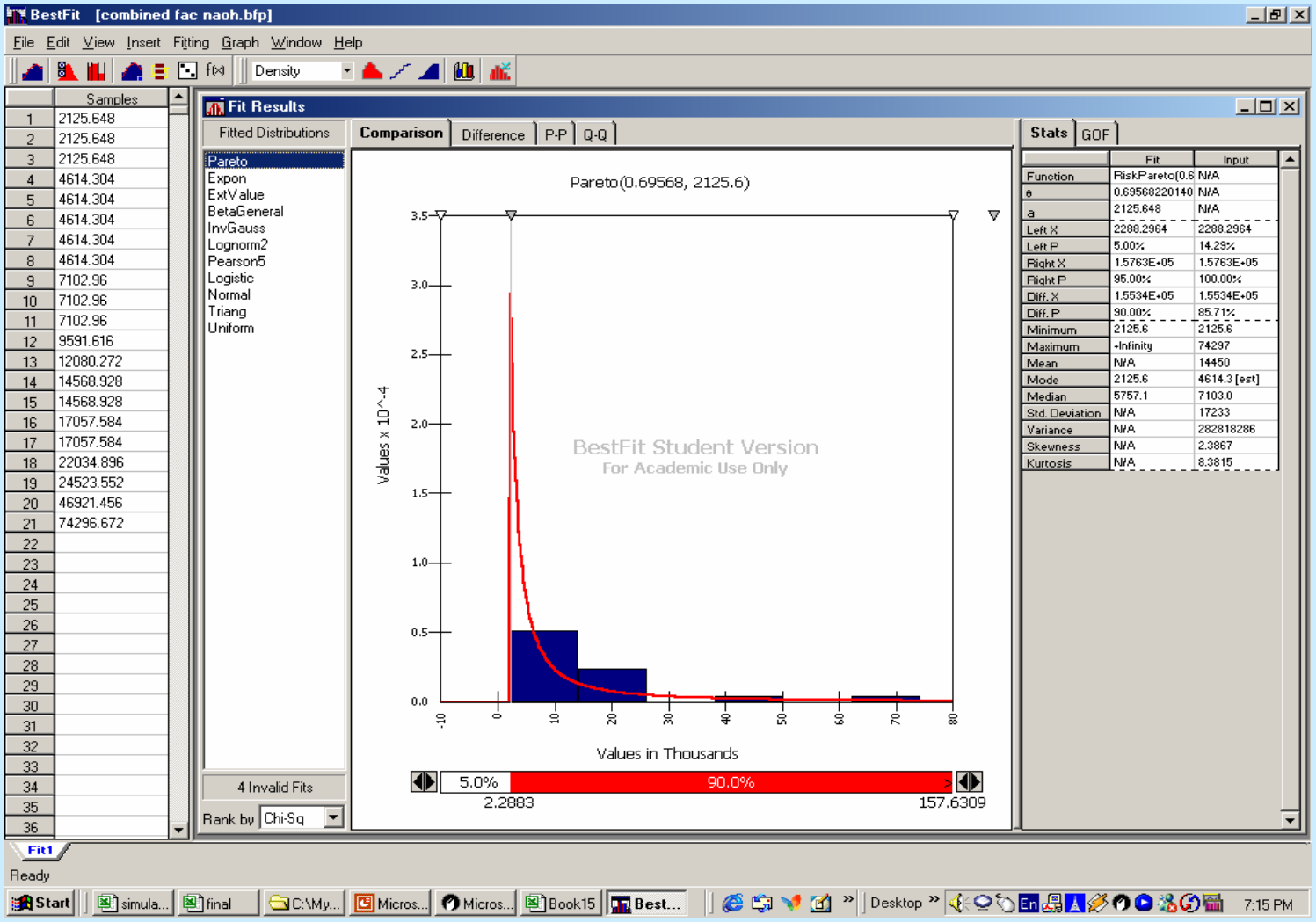
Combined facility

Lime added for alkalinity as CaCO3 requirment(range 0-100000lbs/day)



Combined facility

NaOH added for alkalinity as CaCO3 requirment(range>100000lbs/day)



Combined facility

			lbs/day	tons/day			
Lime		most likely	12532	5.676996	mean=	5.676996	ton/day
		max	56000	25.368			
		min	0	0			
From lime used distribution							
	lime added	66.67					
	lime added<=0	33.33%					
	cost	$72/ton					
		lbs/day	tons/day				
NaOH	mean	14450	6.54585	$320/ton	mean=	6.54585	ton/day
	max	74297	33.656541				
	min	2125.6	0.9628968				
From NaOH used distribution							
	NaOH used	19.20%	< as CaCO3>=100000 lbs/day)				
	cost	$320/ton					
1year use=66.67% x 365 x 5.67 x 72 + 19.20% x 365 x 6.55 x 320							
=	246231.0469						
lime cost	99343.36692						
naoh cost	146887.68						
naoh cost-lime cost	47544.31308						

Combined facility

lime used(lbs/day)	lime used(t0n)	%lime used	lime price(ton)	lime cost
12532	5.676996	0.6667	72	99465.94297

naoh used	naoh used(t0n)	%naoh used	naoh price	naoh cost
14450	6.54585	0.192	320	146794.6138

combined cost
246260.5567

sensitity analysis for combined facility

cost component	type of cost	cost	present worth 3%		max	min
demolition costs	single	1220000	1220000	fixed cost	-	-
capital cost for construcition of new package	single	394000	394000	fixed cost	401880	394000
amount of lime(ton/day)		5.67			25.368	0
price of lime (cost per ton)		70			72	70
annual operation cost for lime facilities	annuity	17453	259654	fixed cost	285619.4	233688.6
annual maintenance cost for lime facilities	annuity	22503	334786	fixed cost	368264.6	301307.4
annual cleaning grid removal cost	annuity	66150	984145	fixed cost	-	-
amount of NaOH		6.54			33.66	0.96
price of NaOH		320			320	256
annual operation cost for NaOH facilities	annuity	17107	254507	fixed cost	279957.7	229056.3
annual maintenance cost for NaOH facilities	annuity	23304	346705	fixed cost	381375.5	312034.5
slaker overhaul(after 10 years)	single	40000	40000	fixed cost	-	-

Manufacturing cost in 20 years	8698742.059

Combined facility

- We estimate the cost of operating Combined facility that equals to $8.6million

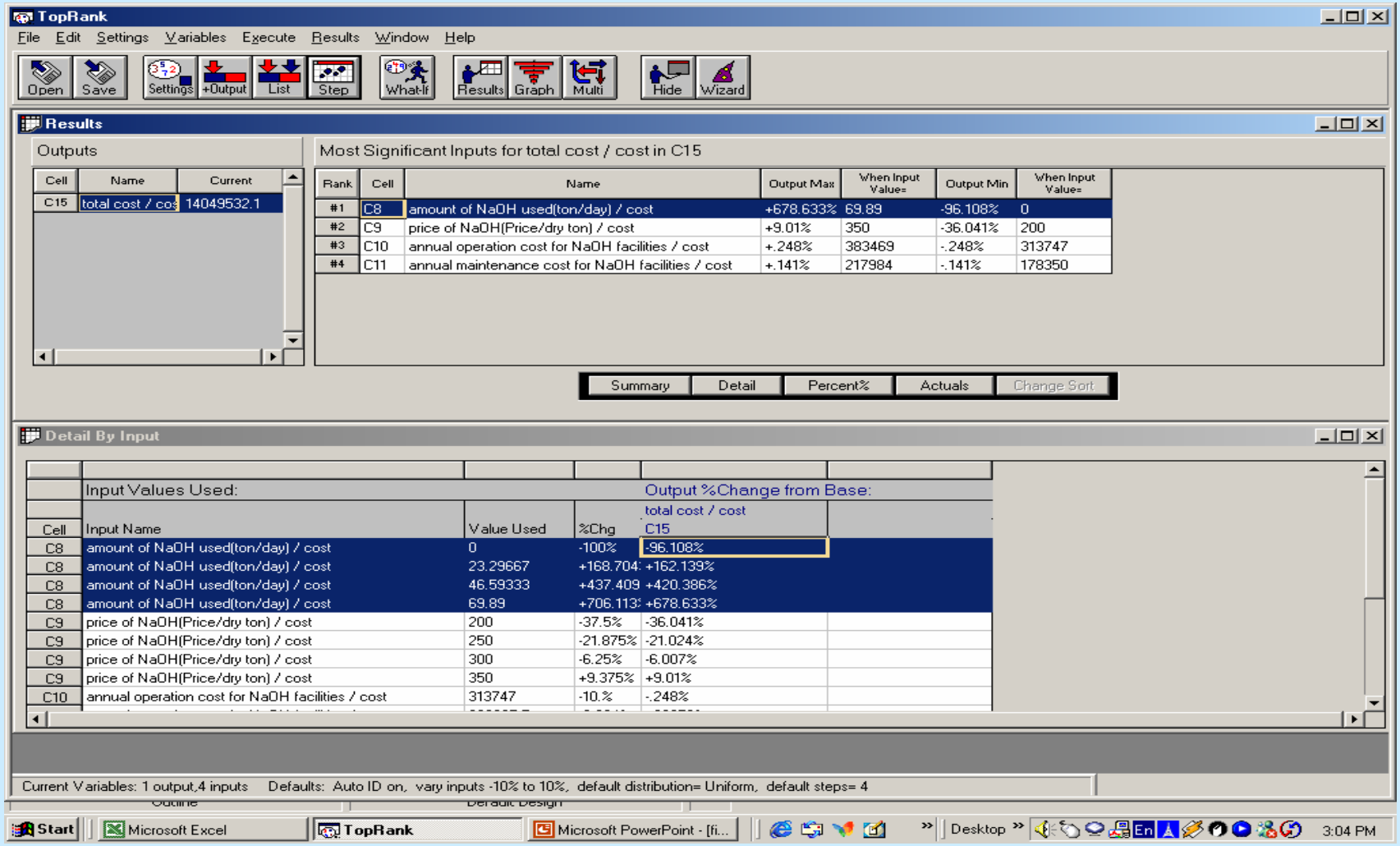
Sensitivity analysis

NaOH facility

Sensitivity analysis NaOH facility						
	1.cost of continued use of the NaOH facility					
	cost component	cost	max	min		
	amount of NaOH used(ton/day)	8.67	69.89	0		
	price of NaOH(Price/dry ton)	320	350	200		
	annual operation cost for NaOH facilities	348609	383469.4	313747.7		
	annual maintenance cost for NaOH facilities	198168	217984.3	178350.8		

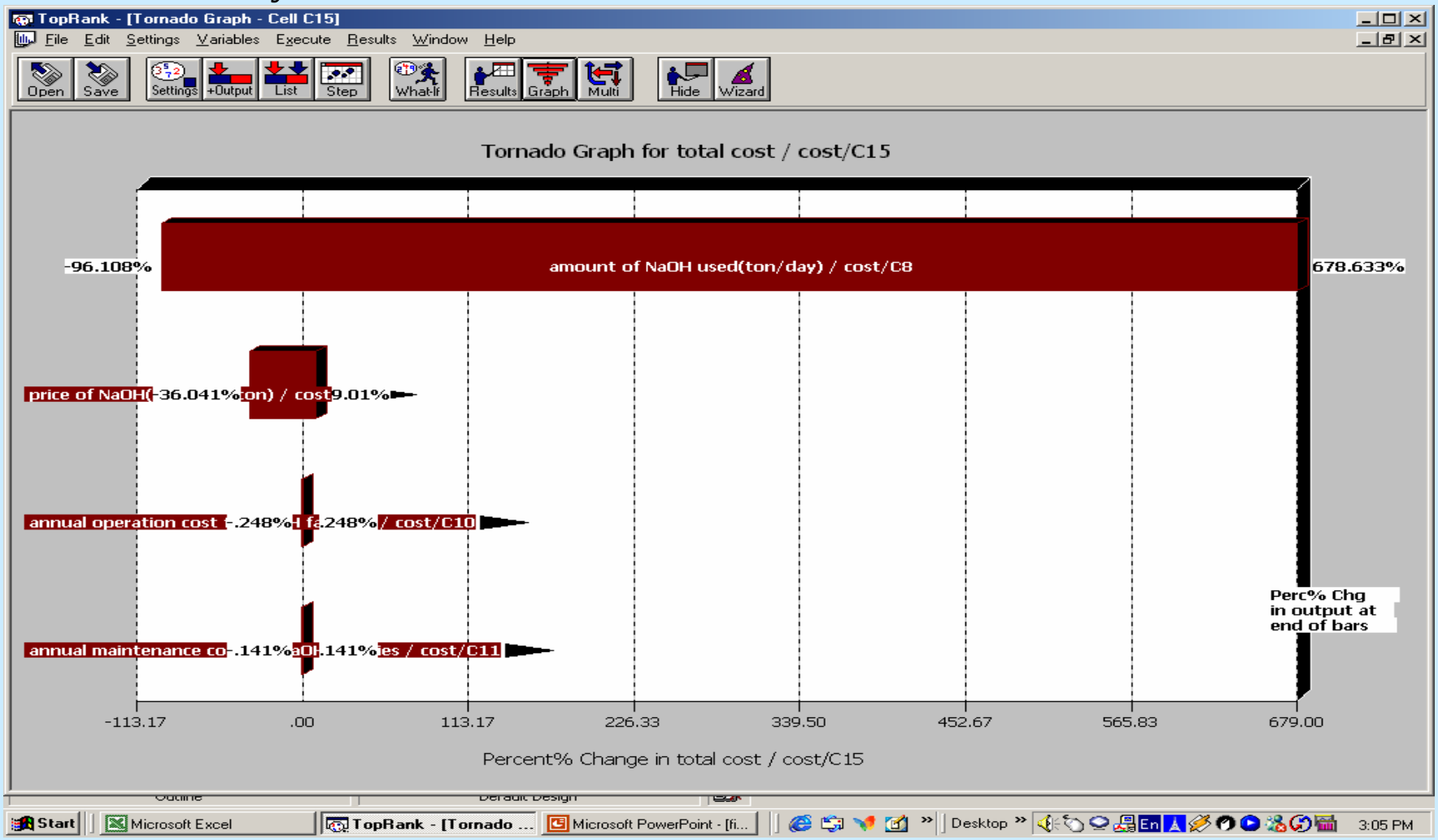
Sensitivity analysis

NaOH facility



Sensitivity analysis

NaOH facility



Sensitivity analysis

Combined facility

sensitity analysis for combined facility					
cost component	cost	present worth 3%	max	min	
demolition costs	1220000	1220000	-	-	
capital cost for construcition of new package	394000	394000	401880	394000	
amount of lime(ton/day)	5.67		25.368	0	
price of lime (cost per ton)	70		72	70	
annual operation cost for lime facilities	17453	259654	285619.4	233688.6	
annual maintenance cost for lime facilities	22503	334786	368264.6	301307.4	
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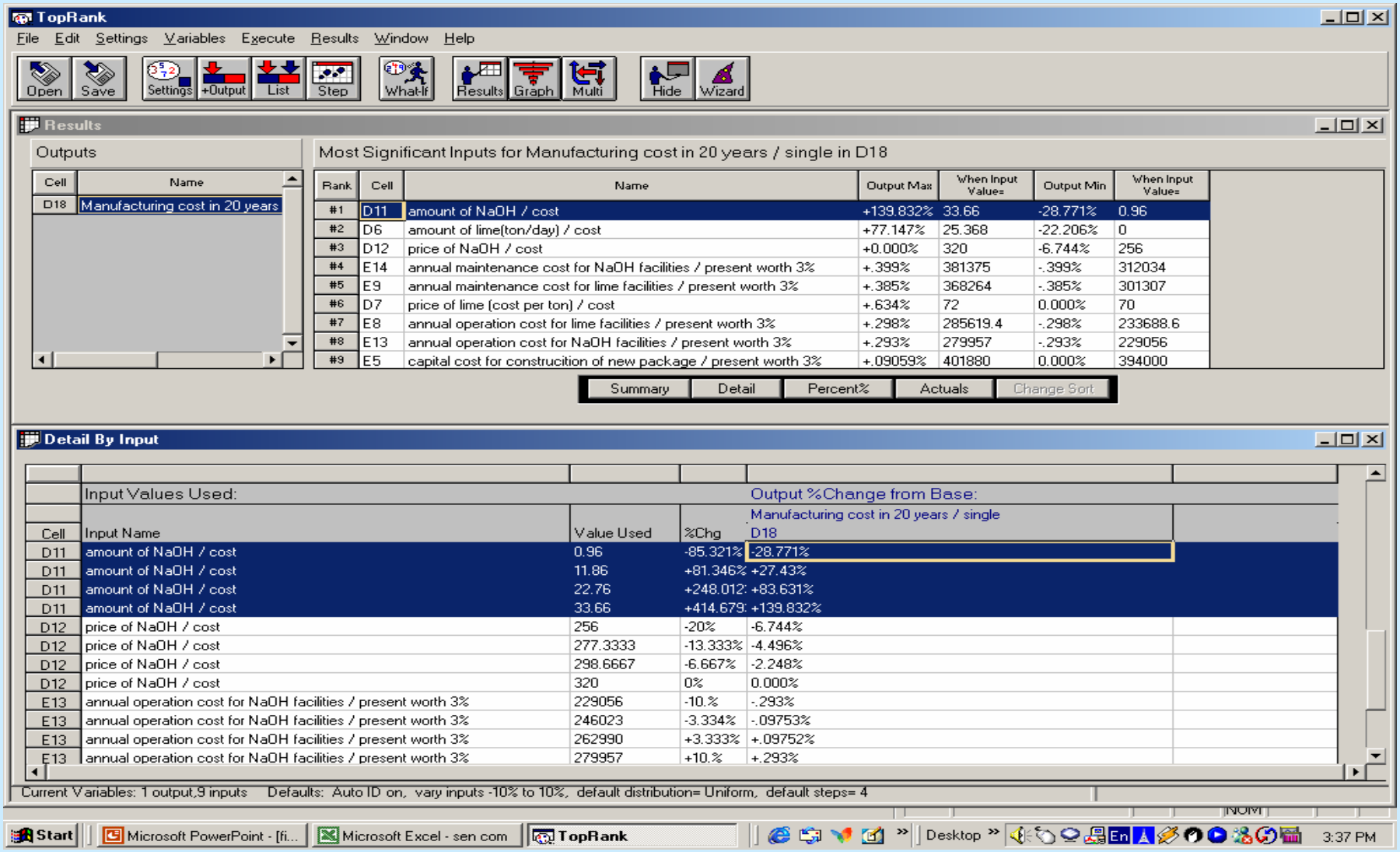
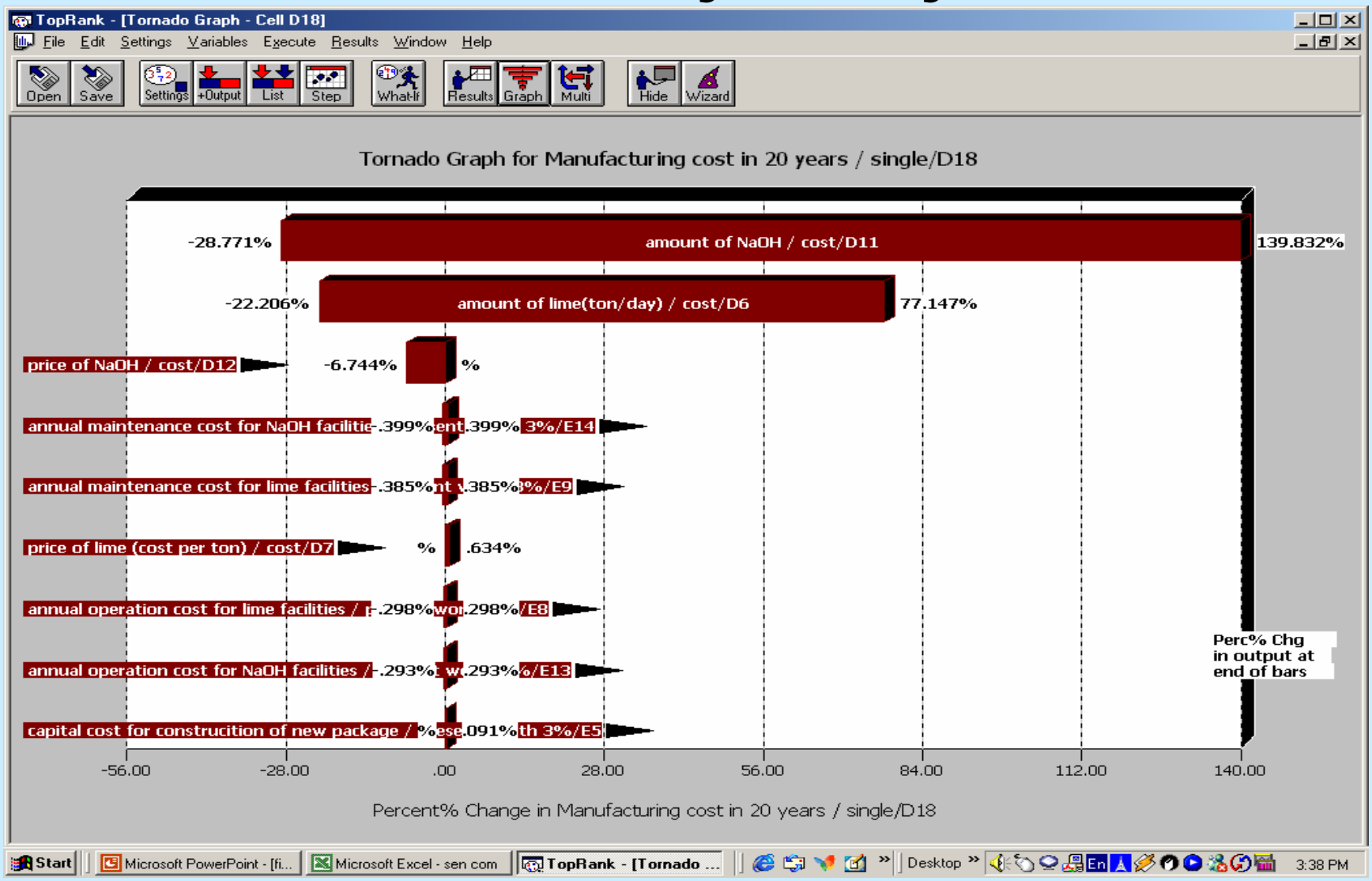
slaker overhaul(after 10 years)	40000	40000	-	-	

Sensitivity analysis

Combined facility



Sensitivity analysis



Sensitivity analysis(summary)

- NaOH facility
- Most significant input
  - 1.amount of NaOH when input maximum, 69.89 tons
  - 2.price NaOH when input maximum
  - 3.annual operation cost
  - 4.annual maintenance cost

Sensitivity analysis(summary)

- Combined facility
- Most significant input
  - 1.amount of NaOH when input 33.66 tons(maximum)
  - 2.amount of Lime (maximum)
  - 3.price NaOH
  - 4.annual maintenance cost NaOH
  - 5.annual maintenance cost Lime
  - 6.price of lime

Simulation

Simulation NaOH facility

input amount NaOH added-triangular

-max 69.89, min 0, most likely 8.67

input price of NaOH-logistic

-alpha 283.34, beta 27.198

input operation cost-uniform

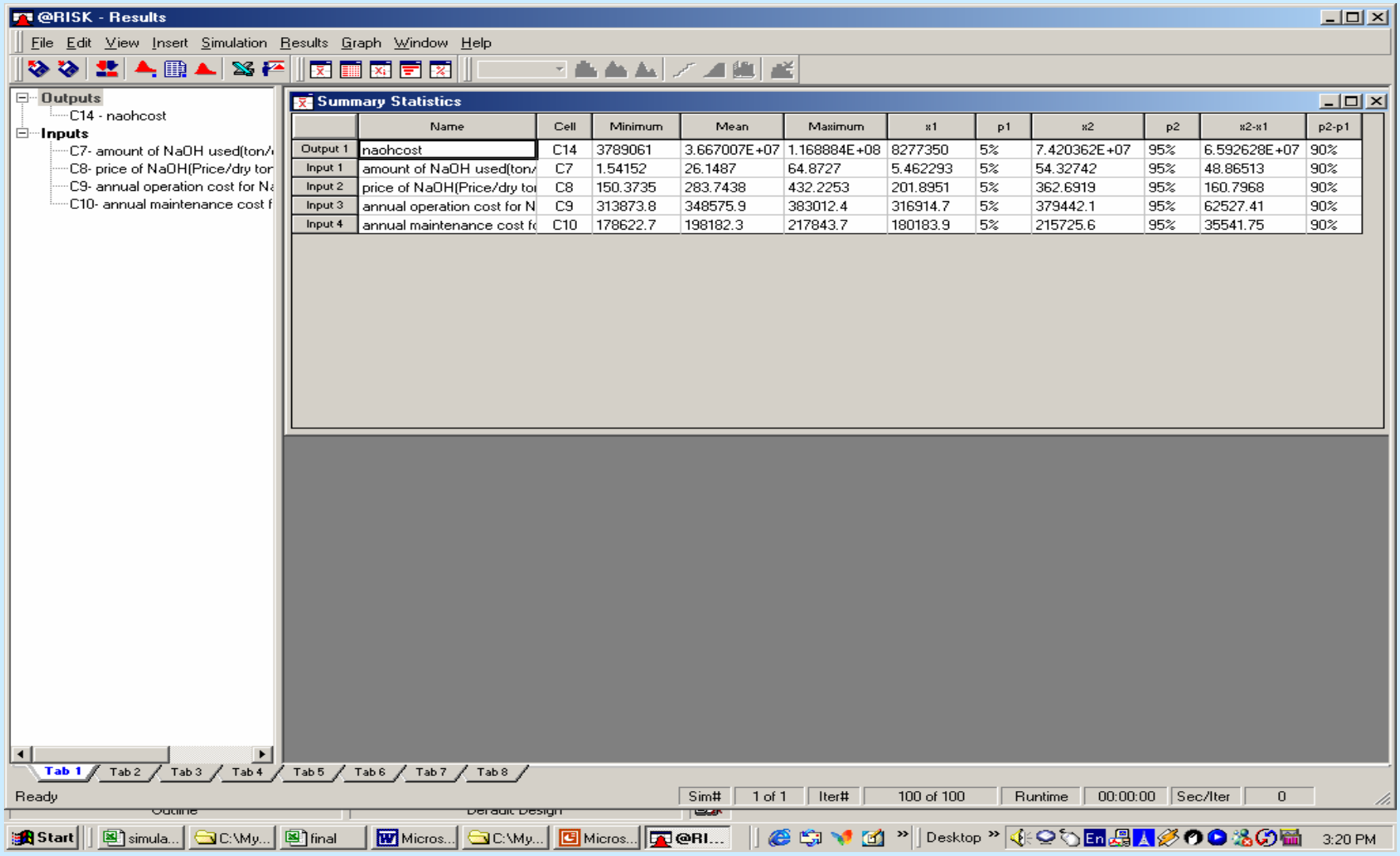
-max 383469, min 313747

input maintenance cost-uniform

-max 217984, min 178350

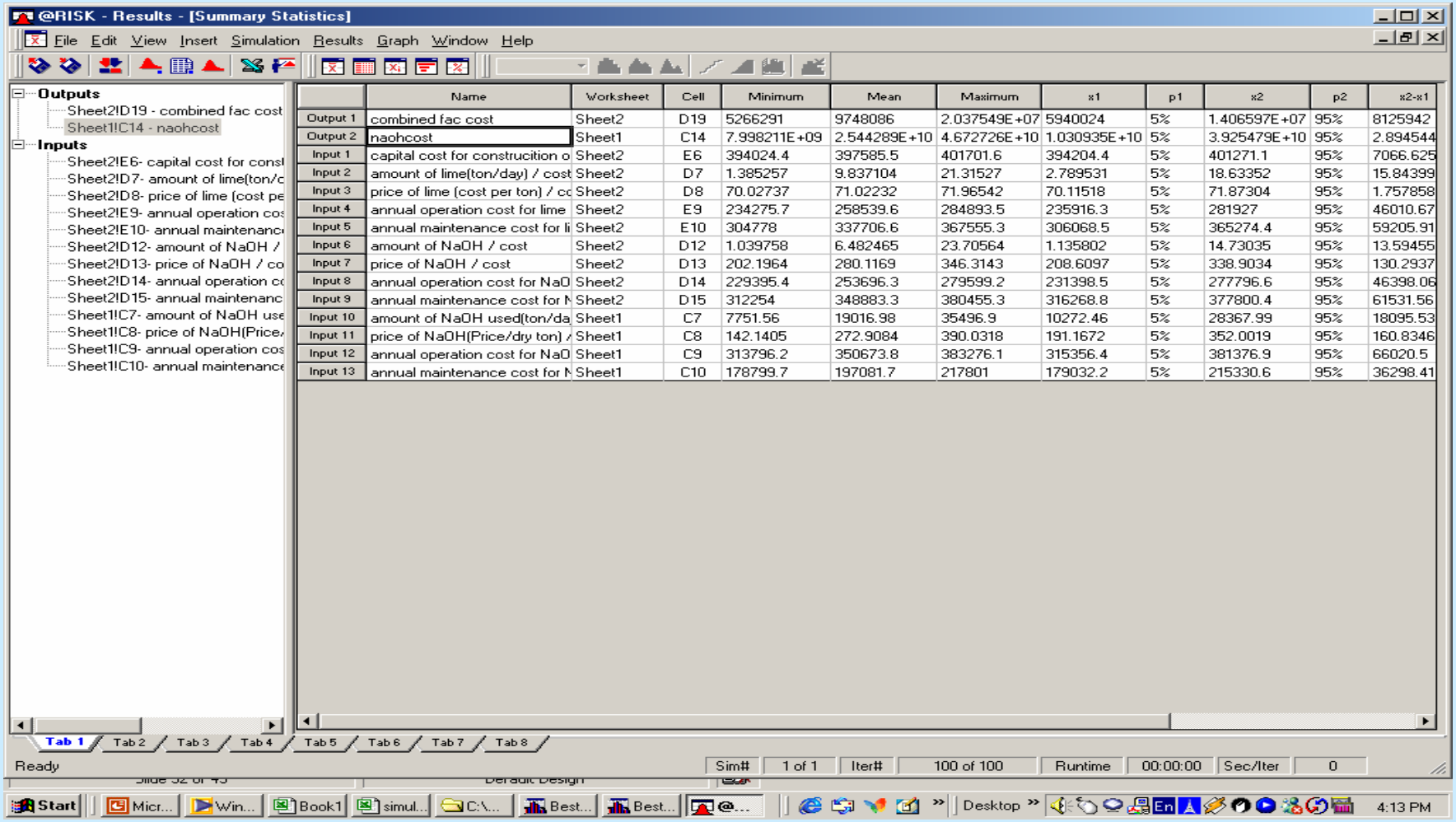
Simulation

Simulation NaOH facility(amount NaOH=tri, price=logistic)



Simulation

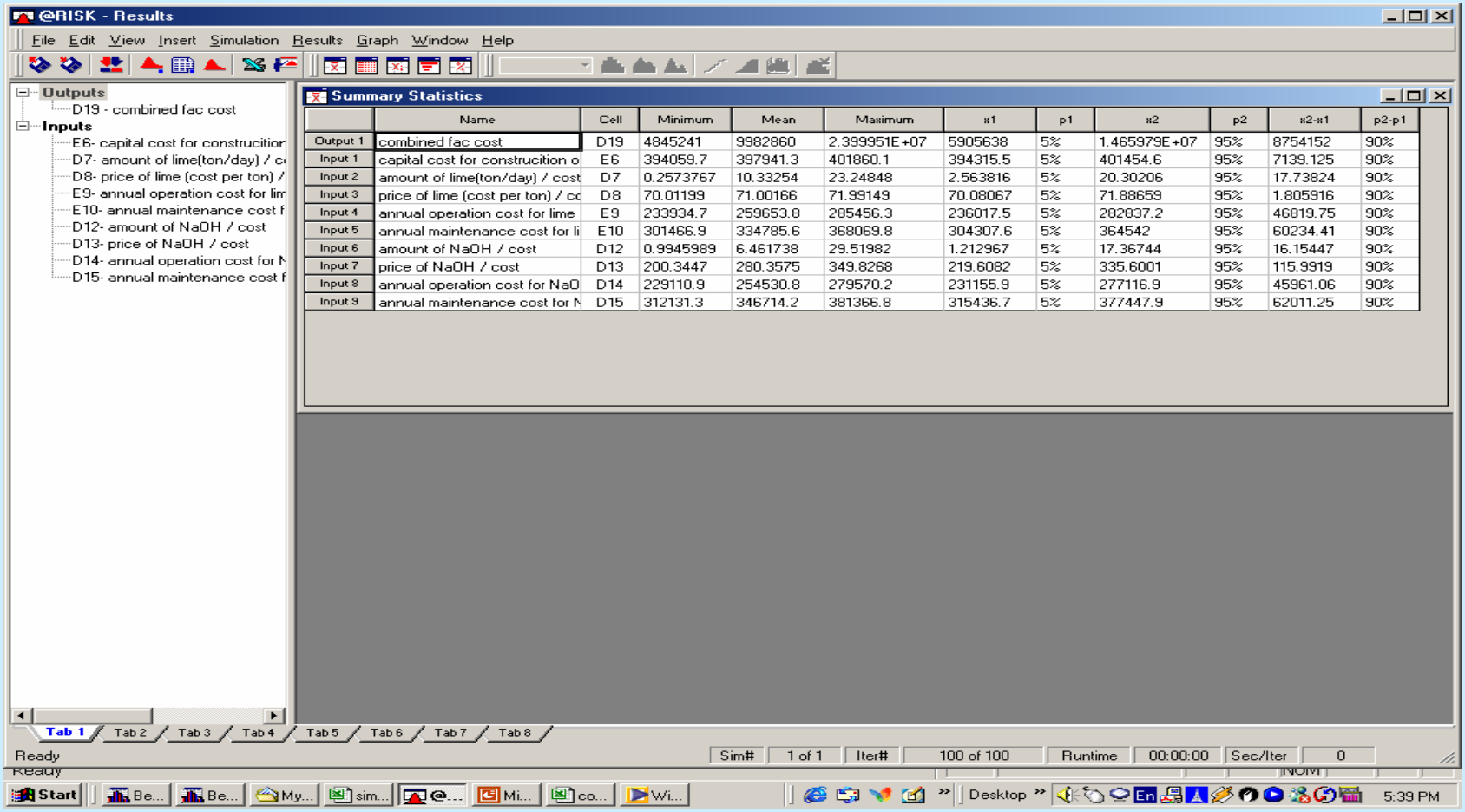
Simulation NaOH facility(amount and price NaOH=normal)



	Name	Worksheet	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2	x2-x1
Output 1	combined fac cost	Sheet2	D19	5266291	9748086	2.037549E+07	5940024	5%	1.406597E+07	95%	8125942
Output 2	naohcost	Sheet1	C14	7.998211E+09	2.544289E+10	4.672726E+10	1.030935E+10	5%	3.925479E+10	95%	2.894544
Input 1	capital cost for construcition o	Sheet2	E6	394024.4	397585.5	401701.6	394204.4	5%	401271.1	95%	7066.625
Input 2	amount of lime(ton/day) / cost	Sheet2	D7	1.385257	9.837104	21.31527	2.789531	5%	18.63352	95%	15.84399
Input 3	price of lime (cost per ton) / co	Sheet2	D8	70.02737	71.02232	71.96542	70.11518	5%	71.87304	95%	1.757858
Input 4	annual operation cost for lime	Sheet2	E9	234275.7	258539.6	284893.5	235916.3	5%	281927	95%	46010.67
Input 5	annual maintenance cost for li	Sheet2	E10	304778	337706.6	367555.3	306068.5	5%	365274.4	95%	59205.91
Input 6	amount of NaOH / cost	Sheet2	D12	1.039758	6.482465	23.70564	1.135802	5%	14.73035	95%	13.59455
Input 7	price of NaOH / cost	Sheet2	D13	202.1964	280.1169	346.3143	208.6097	5%	338.9034	95%	130.2937
Input 8	annual operation cost for NaO	Sheet2	D14	229395.4	253696.3	279599.2	231398.5	5%	277796.6	95%	46398.06
Input 9	annual maintenance cost for N	Sheet2	D15	312254	348883.3	380455.3	316268.8	5%	377800.4	95%	61531.56
Input 10	amount of NaOH used(ton/da	Sheet1	C7	7751.56	19016.98	35496.9	10272.46	5%	28367.99	95%	18095.53
Input 11	price of NaOH(Price/dry ton) /	Sheet1	C8	142.1405	272.9084	390.0318	191.1672	5%	352.0019	95%	160.8346
Input 12	annual operation cost for NaO	Sheet1	C9	313796.2	350673.8	383276.1	315356.4	5%	381376.9	95%	66020.5
Input 13	annual maintenance cost for N	Sheet1	C10	178799.7	197081.7	217801	179032.2	5%	215330.6	95%	36298.41

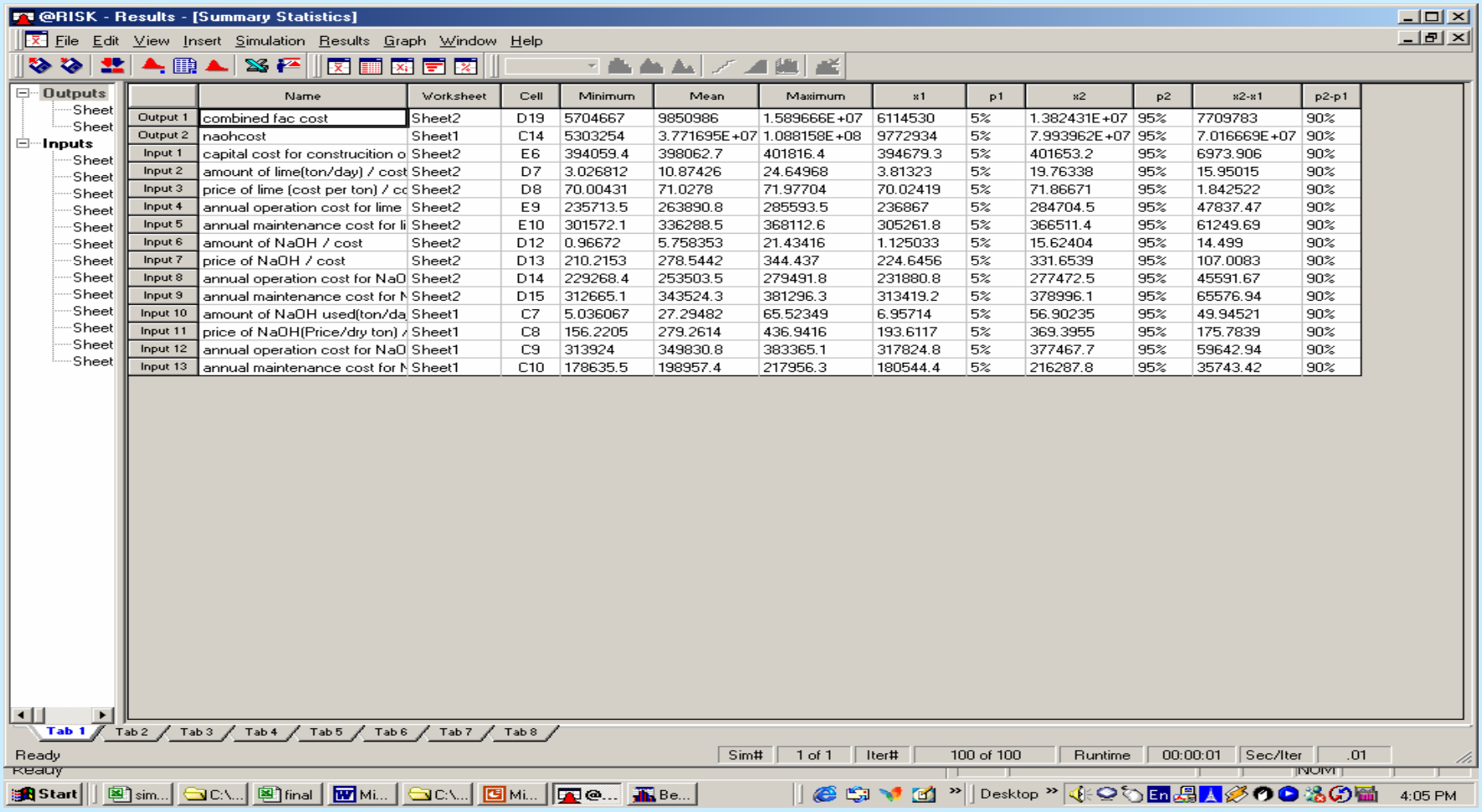
Simulation

Simulation Combined facility



Simulation

Simulation Combined facility



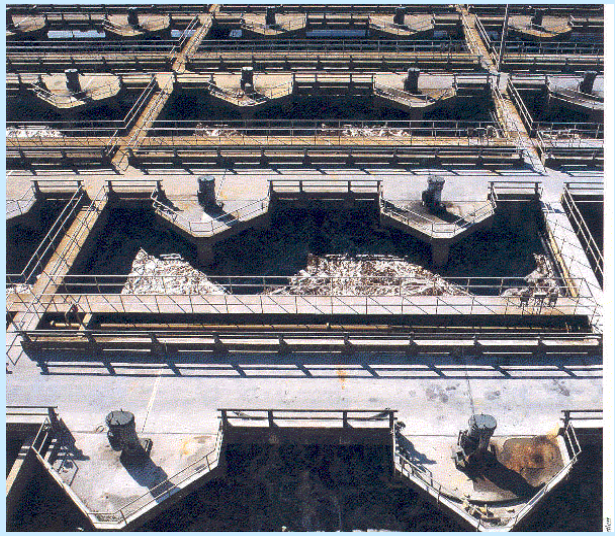
	Name	Worksheet	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2	x2-x1	p2-p1
Output 1	combined fac cost	Sheet2	D19	5704667	9850986	1.589666E+07	6114530	5%	1.382431E+07	95%	7709783	90%
Output 2	naohcost	Sheet1	C14	5303254	3.771695E+07	1.088158E+08	9772934	5%	7.993962E+07	95%	7.016669E+07	90%
Input 1	capital cost for construcition o	Sheet2	E6	394059.4	398062.7	401816.4	394679.3	5%	401653.2	95%	6973.906	90%
Input 2	amount of lime(ton/day) / cost	Sheet2	D7	3.026812	10.87426	24.64968	3.81323	5%	19.76338	95%	15.95015	90%
Input 3	price of lime (cost per ton) / cc	Sheet2	D8	70.00431	71.0278	71.97704	70.02419	5%	71.86671	95%	1.842522	90%
Input 4	annual operation cost for lime	Sheet2	E9	235713.5	263890.8	285593.5	236867	5%	284704.5	95%	47837.47	90%
Input 5	annual maintenance cost for li	Sheet2	E10	301572.1	336288.5	368112.6	305261.8	5%	366511.4	95%	61249.69	90%
Input 6	amount of NaOH / cost	Sheet2	D12	0.96672	5.758353	21.43416	1.125033	5%	15.62404	95%	14.499	90%
Input 7	price of NaOH / cost	Sheet2	D13	210.2153	278.5442	344.437	224.6456	5%	331.6539	95%	107.0083	90%
Input 8	annual operation cost for NaO	Sheet2	D14	229268.4	253503.5	279491.8	231880.8	5%	277472.5	95%	45591.67	90%
Input 9	annual maintenance cost for N	Sheet2	D15	312665.1	343524.3	381296.3	313419.2	5%	378996.1	95%	65576.94	90%
Input 10	amount of NaOH used(ton/da	Sheet1	C7	5.036067	27.29482	65.52349	6.95714	5%	56.90235	95%	49.94521	90%
Input 11	price of NaOH(Price/dry ton) /	Sheet1	C8	156.2205	279.2614	436.9416	193.6117	5%	369.3955	95%	175.7839	90%
Input 12	annual operation cost for NaO	Sheet1	C9	313924	349830.8	383365.1	317824.8	5%	377467.7	95%	59642.94	90%
Input 13	annual maintenance cost for N	Sheet1	C10	178635.5	198957.4	217956.3	180544.4	5%	216287.8	95%	35743.42	90%

Simulation summary

NaOH facility		mean	max	95%		
	amount NaOH=triangular	35	98	73		
	price=logistic					
	amount NaOH=normal					
	price=normal	12	21	18		
	amount NaOH=normal	12	26	18		
	price=logistic					
	amount NaOH=triangular	36	102	77		
	price=normal					
Combined facility		mean	max	95%		
	amount of lime=tri	9.9	23	14		
	amount NaOH=exponential					
	price=logistic					
	amount of lime=normal	8.4	28	18		
	amount NaOH=exponential					
	price=logistic					
	amount of lime=normal	8.4	24	19		
	amount NaOH=exponential					

Simulation summary

- By changing different distributions to the significant inputs, the result shows that operating the second alternative, “combined facility”, is more benefitial than operating only NaOH facility.



Project summary

- We choose the alternative two, “combined facility”. Even though we have to pay a capital for building a new lime facility, we can get more benefit from this alternative when we consider about long-run profit(20 years).
- However, running these facilities we have to focus on amount of NaOH, amount of Lime, and price of NaOH respectively, according to sensitivity analysis.

Future work

- Knowing the price of NaOH in the past 3 years, we can find the forecasting method and forecast for the budget plan in the future.
- We haven’t included the safety issue in this problem and it may effect the decision even the operator in these facility are about 20 persons.

Future work

- We can search for the possibility that these operators may be sick, quit for their job according to the health problem, and cost of training new operator.
- However, right now DCWASA already decide to construct a new lime facility according to the cost benefit and there is some belief that the lime also improve the settling of wastewater.