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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

C o m p i l a t i o n

The code solves the problem for a single TMDL (not the whole range) to get

the

detail data on each problem solution.

The code solves te deterministic trading problem for Mercury.

The choice is between a set of possible treatment options and the option o

f

trading.

The details of the three treatement technologies are:

1. Coagulation and Filteration

2. Activated Carbon

3. Ion Exchange

The code takes the value of TMDL and does the rest of the calculations aut

omatically.

This will be used to see the variations of the results with TMDL changes.

The code also considers the health cost for the humans. So an increased TM

DL

results in an increased value of the health. The health cost is derived fr

om the

WQS, the resulting conc. of Hg in fishes, the LC50 value for the aquatic l

ife

(assumed to be close to that of humans) and the dietary intake of fish by

humans.

19

20 Sets i Number of industries /1\*29/

21 j Number of treatment options /1\*3/

22 alias(i,k);

23

24 Parameter TMDL Total Maximum Daily Load /32/

25 HSC Highest Segment Concentration (ng per lit) /5.0/

26 CAL Current Annual Load (Kilograms per year) /58.8/

27

28 r trading ratio /1.1/

29 F trading transaction cost (dollars per Kg) /400000000/

30

31 TC Plant costs for the three technologies /1 1.0,2 1.55,3 0.65/

32 q Reductions possible by the treatment technologies /1 2,2 3,3 1/

33

34 water\_intake Intake of water by an average individual per day in

liters /2.0/

35 fish\_intake Intake of fish food by an everage individual in kg pe

r day /0.0175/

36 safe\_hg Safe concentration of Hg in fishes in mg per kg /0.4/

37 LC50 The LC50 value of HG (taken from fishes) in micrograms per l

iter /350/

38

39 Compensation Compensation for each dead person in dollar /1000000

/

40 population total population consuming the water /10000/;

41

42

43 Table Data Date related to the industries

44 \*Data(i,1) is the total volumetric discharge in MGD

45 \*Data(i,2) is the current discharge concentration in nanograms/liter

46 \*Data(i,3) is the available capital with the industry in Million Dollars

47 1 2 3

48 1 46.1 4.65 68

49 2 1.5 3.7 8

50 3 4.6 4.3 15

51 4 1.5 3.4 5

52 5 2 3.88 10

53 6 2.24 3.7 12

54 7 1.2 3.9 9

55 8 27 4.83 30

56 9 4.5 4.0 15

57 10 1 3.1 5

58 11 1 3.06 5

59 12 1 3.22 5

60 13 2 3.31 9

61 14 3.765 4.8 10

62 15 18 4.33 60

63 16 7.2 5.1 20

64 17 58.6 4.87 100

65 18 23 4.52 40

66 19 1.152 5.05 10

67 20 0.362 4.14 5

68 21 108 4.58 130

69 22 4.68 5.2 12

70 23 28.09 4.41 45

71 24 1.921 3.9 10

72 25 0.544 4.5 7

73 26 0.5 3.95 10

74 27 0.003 3.72 5

75 28 1.246 4.1 5

76 29 0.054 3.4 3;

77

78

79 scalar k1 conversion from gallons to liters /3.7845/

80 k2 scalar used as a couter;

81

82 Parameter cost cost incurred by each industry due to waste treatment setup

83 cost\_total The total overall cost incurred which is to be minimiz

ed

84 cost\_combined Combined cost including the technology cost and hea

lth care cost

85 cost\_health The actual health cost incurred due to the pollutant

discharge

86 target\_reduction The total reduction from all the industries targ

etted

87 red\_final Final reduction in the discharge achieved by each indus

try after optimization

88 red\_total The final combined reduction from the industries

89 WQS Water Quality Standard (ng per lit)

90 WQS\_final Final water standard achieved after reduction

91 WQS\_avg The average WQS for the industries after the reduction

92 reduction Desired reduction in Kg per year

93 mortality The number of people dying due to the contamination

94

95 Tech\_cost cost incurred by each industry due to waste treatment s

etup

96 Tech\_cost\_total The total overall cost incurred which is to be mi

nimized

97

98 Results To store and display the final results;

99

100 Parameter v

101 u;

102

103 WQS=(HSC/CAL)\*TMDL;

104 reduction(i,'1')=(Data(i,'2')-WQS)\*Data(i,'1')\*k1\*10\*\*(-6)\*365;

105

106 binary variables b binary variable specifying the process selection;

107

108 variable t Variable deciding the amount of mercury traded between various

industries

109 Tobj Objective function

110 obj Objective function;

111

112 \*=========================================================================

======

113 \* First solving the Technology only model to generate constraints for the

problem

114 \* The constraint states that no industry should be required to spend more

as a results

115 \* of trading.

116 \* Definig the Technology only problem

117 Equations Tobjective

118 Tc1

119 Tc3;

120

121 Tobjective.. Tobj =e=1000\*365\*sum((i,j),TC(j)\*Data(i,'1')\*b(i,j));

122 Tc1(i).. sum(j,b(i,j)) =l= 3;

123 Tc3(i).. 10\*\*(-6)\*k1\*365\*sum(j,q(j)\*Data(i,'1')\*b(i,j)) =g= reduction(i,'1

');

124 \* The reduction constraint is multiplied by 1000 on both sides to avoid

125 \* numerical errors arising due to small values.

126

127 model Tech\_problem /Tobjective, Tc1, Tc3/;

128

129

130

131

132

133

134 \*=========================================================================

======

135

136 \* Definig the Trading option problem

137 Equations objective

138 c1

139 c3

140 c4

141 c5

142 c6;

143

144 objective.. obj =e= 1000\*365\*sum((i,j),TC(j)\*Data(i,'1')\*b(i,j));

145 c1(i).. sum(j,b(i,j)) =l= 3;

146 c3(i).. t(i,i) =e= 0;

147 c4(i).. 10\*\*(-6)\*k1\*365\*sum(j,q(j)\*Data(i,'1')\*b(i,j))+(sum(k,t(i,k))-r\*su

m(k,t(k,i))) =g= reduction(i,'1');

148 \* Expressing the trading and reduction quantities in grams/year to inceras

e absolute values

149 c5(i).. Tech\_cost(i) =g= 1000\*365\*sum(j,b(i,j)\*Data(i,'1')\*TC(j))+F\*(sum(k

,t.l(i,k))-sum(k,t.l(k,i)))/1000;

150 c6(i).. 10\*\*(-6)\*k1\*365\*sum(j,q(j)\*Data(i,'1')\*b(i,j))+(sum(k,t(i,k))-r\*su

m(k,t(k,i))) =g= 0;

151 t.lo(i,k) = 0;

152

153 model problem /objective,c1, c3, c4, c5, c6/;

154

155 \*=== Solving the Technology only problem to generate constraint for the ma

in problem===

156 options Optcr=0.001;

157 solve Tech\_problem using mip minimizing Tobj;

158

159 Tech\_cost(i)=1000\*365\*sum(j,b.l(i,j)\*Data(i,'1')\*TC(j));

160 Tech\_cost\_total=sum(i,Tech\_cost(i));

161 \*=========================================================================

======

162

163 options Optcr=0.001;

164 solve problem using mip minimizing obj;

165

166

167

168

169

170

171

172

173

174 target\_reduction=sum(i,reduction(i,'1'));

175

176 \*=========================================================================

======

177 red\_final(i,'1')=10\*\*(-6)\*k1\*365\*sum(j,q(j)\*Data(i,'1')\*b.l(i,j))+(sum(k,t

.l(i,k))-r\*sum(k,t.l(k,i)));

178 red\_total=sum(i,red\_final(i,'1'));

179 \* In grams/year

180

181 cost(i,'1')=1000\*365\*sum(j,b.l(i,j)\*Data(i,'1')\*TC(j))+F\*(sum(k,t.l(i,k))-

sum(k,t.l(k,i)))/1000;

182 cost\_total=sum(i,cost(i,'1'));

183 \*=========================================================================

======

184 u(i,k)=t.l(k,i);

185

186 \* Calculation of the actual health care cost after the actual discharges a

re known from the solution

187 WQS\_final(i,'1')=Data(i,'2')-red\_final(i,'1')/(Data(i,'1')\*k1\*10\*\*(-6)\*365

);

188 \* The second term in this equation converts the final reduction in the uni

ts of micro-grams/liter.

189 \* The Data(i,'2') is also in same units so the WQS\_final is also in micro-

grams/liter.

190

191 WQS\_avg=sum(i,WQS\_final(i,'1')\*(Data(i,'1')\*k1\*10\*\*(-6)\*365))/sum(i,(Data(

i,'1')\*k1\*10\*\*(-6)\*365));

192 mortality=((WQS\_avg\*safe\_hg/2.8)\*fish\_intake\*1000\*0.5\*population/(LC50\*wat

er\_intake));

193

194 cost\_health=mortality\*compensation;

195 cost\_combined=cost\_total+cost\_health;

196

197 v=sum((i,k), t.l(i,k));

198

199 Results('1','1')=red\_total;

200 Results('1','2')=cost\_health;

201 Results('1','3')=cost\_total;

202 Results('1','4')=cost\_combined;

203 Results('1','5')=v;

204

205 display WQS, red\_final,WQS\_final, b.l, Results, cost, t.l;

COMPILATION TIME = 0.000 SECONDS 3 MB 24.1.3 r41464 WEX-WEI

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Equation Listing SOLVE Tech\_problem Using MIP From line 157

---- Tobjective =E=

Tobjective.. - 16826500\*b(1,1) - 26081075\*b(1,2) - 10937225\*b(1,3)

- 547500\*b(2,1) - 848625\*b(2,2) - 355875\*b(2,3) - 1679000\*b(3,1)

- 2602450\*b(3,2) - 1091350\*b(3,3) - 547500\*b(4,1) - 848625\*b(4,2)

- 355875\*b(4,3) - 730000\*b(5,1) - 1131500\*b(5,2) - 474500\*b(5,3)

- 817600\*b(6,1) - 1267280\*b(6,2) - 531440\*b(6,3) - 438000\*b(7,1)

- 678900\*b(7,2) - 284700\*b(7,3) - 9855000\*b(8,1) - 15275250\*b(8,2)

- 6405750\*b(8,3) - 1642500\*b(9,1) - 2545875\*b(9,2) - 1067625\*b(9,3)

- 365000\*b(10,1) - 565750\*b(10,2) - 237250\*b(10,3) - 365000\*b(11,1)

- 565750\*b(11,2) - 237250\*b(11,3) - 365000\*b(12,1) - 565750\*b(12,2)

- 237250\*b(12,3) - 730000\*b(13,1) - 1131500\*b(13,2) - 474500\*b(13,3)

- 1374225\*b(14,1) - 2130048.75\*b(14,2) - 893246.25\*b(14,3)

- 6570000\*b(15,1) - 10183500\*b(15,2) - 4270500\*b(15,3) - 2628000\*b(16,1)

- 4073400\*b(16,2) - 1708200\*b(16,3) - 21389000\*b(17,1) - 33152950\*b(17,2)

- 13902850\*b(17,3) - 8395000\*b(18,1) - 13012250\*b(18,2) - 5456750\*b(18,3)

- 420480\*b(19,1) - 651744\*b(19,2) - 273312\*b(19,3) - 132130\*b(20,1)

- 204801.5\*b(20,2) - 85884.5\*b(20,3) - 39420000\*b(21,1) - 61101000\*b(21,2)

- 25623000\*b(21,3) - 1708200\*b(22,1) - 2647710\*b(22,2) - 1110330\*b(22,3)

- 10252850\*b(23,1) - 15891917.5\*b(23,2) - 6664352.5\*b(23,3)

- 701165\*b(24,1) - 1086805.75\*b(24,2) - 455757.25\*b(24,3) - 198560\*b(25,1)

- 307768\*b(25,2) - 129064\*b(25,3) - 182500\*b(26,1) - 282875\*b(26,2)

- 118625\*b(26,3) - 1095\*b(27,1) - 1697.25\*b(27,2) - 711.75\*b(27,3)

- 454790\*b(28,1) - 704924.5\*b(28,2) - 295613.5\*b(28,3) - 19710\*b(29,1)

- 30550.5\*b(29,2) - 12811.5\*b(29,3) + Tobj =E= 0 ; (LHS = 0)

---- Tc1 =L=

Tc1(1).. b(1,1) + b(1,2) + b(1,3) =L= 3 ; (LHS = 0)

Tc1(2).. b(2,1) + b(2,2) + b(2,3) =L= 3 ; (LHS = 0)

Tc1(3).. b(3,1) + b(3,2) + b(3,3) =L= 3 ; (LHS = 0)

REMAINING 26 ENTRIES SKIPPED

---- Tc3 =G=

Tc3(1).. 0.1273597785\*b(1,1) + 0.19103966775\*b(1,2) + 0.0636798892499999\*b(1,3)

=G= 0.122832874808418 ; (LHS = 0, INFES = 0.122832874808418 \*\*\*\*)

Tc3(2).. 0.00414402749999999\*b(2,1) + 0.00621604124999999\*b(2,2)

+ 0.00207201375\*b(2,3) =G= 0.00202831822193877 ;

(LHS = 0, INFES = 0.00202831822193877 \*\*\*\*)

Tc3(3).. 0.012708351\*b(3,1) + 0.0190625265\*b(3,2) + 0.00635417549999999\*b(3,3)

=G= 0.0100326811806122 ; (LHS = 0, INFES = 0.0100326811806122 \*\*\*\*)

REMAINING 26 ENTRIES SKIPPED

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Column Listing SOLVE Tech\_problem Using MIP From line 157

---- b binary variable specifying the process selection

b(1,1)

(.LO, .L, .UP, .M = 0, 0, 1, 0)

-1.682650E+7 Tobjective

1 Tc1(1)

0.1274 Tc3(1)

b(1,2)

(.LO, .L, .UP, .M = 0, 0, 1, 0)

-2.608108E+7 Tobjective

1 Tc1(1)

0.191 Tc3(1)

b(1,3)

(.LO, .L, .UP, .M = 0, 0, 1, 0)

-1.093723E+7 Tobjective

1 Tc1(1)

0.0637 Tc3(1)

REMAINING 84 ENTRIES SKIPPED

---- Tobj Objective function

Tobj

(.LO, .L, .UP, .M = -INF, 0, +INF, 0)

1 Tobjective

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Model Statistics SOLVE Tech\_problem Using MIP From line 157

MODEL STATISTICS

BLOCKS OF EQUATIONS 3 SINGLE EQUATIONS 59

BLOCKS OF VARIABLES 2 SINGLE VARIABLES 88

NON ZERO ELEMENTS 262 DISCRETE VARIABLES 87

GENERATION TIME = 0.016 SECONDS 4 MB 24.1.3 r41464 WEX-WEI

EXECUTION TIME = 0.016 SECONDS 4 MB 24.1.3 r41464 WEX-WEI

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Solution Report SOLVE Tech\_problem Using MIP From line 157

S O L V E S U M M A R Y

MODEL Tech\_problem OBJECTIVE Tobj

TYPE MIP DIRECTION MINIMIZE

SOLVER CPLEX FROM LINE 157

\*\*\*\* SOLVER STATUS 1 Normal Completion

\*\*\*\* MODEL STATUS 1 Optimal

\*\*\*\* OBJECTIVE VALUE 147997061.0000

RESOURCE USAGE, LIMIT 0.141 1000.000

ITERATION COUNT, LIMIT 0 2000000000

IBM ILOG CPLEX 24.1.3 r41464 Released Jul 26, 2013 WEI x86\_64/MS Windows

--- GAMS/Cplex licensed for continuous and discrete problems.

Cplex 12.5.1.0

MIP status(101): integer optimal solution

Cplex Time: 0.12sec (det. 6.99 ticks)

Fixing integer variables, and solving final LP...

Fixed MIP status(1): optimal

Cplex Time: 0.00sec (det. 0.05 ticks)

Proven optimal solution.

MIP Solution: 147997061.000000 (0 iterations, 0 nodes)

Final Solve: 147997061.000000 (0 iterations)

Best possible: 147997061.000000

Absolute gap: 0.000000

Relative gap: 0.000000

LOWER LEVEL UPPER MARGINAL

---- EQU Tobjective . . . 1.000

---- EQU Tc1

LOWER LEVEL UPPER MARGINAL

1 -INF 1.000 3.000 .

2 -INF 1.000 3.000 .

3 -INF 1.000 3.000 .

4 -INF 1.000 3.000 .

5 -INF 1.000 3.000 .

6 -INF 1.000 3.000 .

7 -INF 1.000 3.000 .

8 -INF 1.000 3.000 .

9 -INF 1.000 3.000 .

10 -INF 1.000 3.000 .

11 -INF 1.000 3.000 .

12 -INF 1.000 3.000 .

13 -INF 1.000 3.000 .

14 -INF 1.000 3.000 .

15 -INF 1.000 3.000 .

16 -INF 1.000 3.000 .

17 -INF 1.000 3.000 .

18 -INF 1.000 3.000 .

19 -INF 1.000 3.000 .

20 -INF 1.000 3.000 .

21 -INF 1.000 3.000 .

22 -INF 1.000 3.000 .

23 -INF 1.000 3.000 .

24 -INF 1.000 3.000 .

25 -INF 1.000 3.000 .

26 -INF 1.000 3.000 .

27 -INF 1.000 3.000 .

28 -INF 1.000 3.000 .

29 -INF 1.000 3.000 .

---- EQU Tc3

LOWER LEVEL UPPER MARGINAL

1 0.123 0.127 +INF .

2 0.002 0.002 +INF .

3 0.010 0.013 +INF .

4 0.001 0.002 +INF .

5 0.003 0.006 +INF .

6 0.003 0.003 +INF .

7 0.002 0.003 +INF .

8 0.079 0.112 +INF .

9 0.008 0.012 +INF .

10 5.2341E-4 0.001 +INF .

11 4.6815E-4 0.001 +INF .

12 6.8917E-4 0.001 +INF .

13 0.002 0.003 +INF .

14 0.011 0.016 +INF .

15 0.040 0.050 +INF .

16 0.024 0.030 +INF .

17 0.174 0.243 +INF .

18 0.057 0.064 +INF .

19 0.004 0.005 +INF .

20 7.0952E-4 0.001 +INF .

21 0.277 0.298 +INF .

22 0.016 0.019 +INF .

23 0.066 0.078 +INF .

24 0.003 0.005 +INF .

25 0.001 0.002 +INF .

26 8.4877E-4 0.001 +INF .

27 4.1395E-6 4.1395E-6 +INF .

28 0.002 0.003 +INF .

29 5.0642E-5 7.4592E-5 +INF .

---- VAR b binary variable specifying the process selection

LOWER LEVEL UPPER MARGINAL

1 .1 . 1.000 1.000 1.6827E+7

1 .2 . . 1.000 2.6081E+7

1 .3 . . 1.000 1.0937E+7

2 .1 . . 1.000 5.4750E+5

2 .2 . . 1.000 8.4863E+5

2 .3 . 1.000 1.000 3.5588E+5

3 .1 . 1.000 1.000 1.6790E+6

3 .2 . . 1.000 2.6025E+6

3 .3 . . 1.000 1.0913E+6

4 .1 . . 1.000 5.4750E+5

4 .2 . . 1.000 8.4863E+5

4 .3 . 1.000 1.000 3.5588E+5

5 .1 . 1.000 1.000 7.3000E+5

5 .2 . . 1.000 1.1315E+6

5 .3 . . 1.000 4.7450E+5

6 .1 . . 1.000 8.1760E+5

6 .2 . . 1.000 1.2673E+6

6 .3 . 1.000 1.000 5.3144E+5

7 .1 . 1.000 1.000 4.3800E+5

7 .2 . . 1.000 6.7890E+5

7 .3 . . 1.000 2.8470E+5

8 .1 . . 1.000 9.8550E+6

8 .2 . 1.000 1.000 1.5275E+7

8 .3 . . 1.000 6.4058E+6

9 .1 . 1.000 1.000 1.6425E+6

9 .2 . . 1.000 2.5459E+6

9 .3 . . 1.000 1.0676E+6

10.1 . . 1.000 3.6500E+5

10.2 . . 1.000 5.6575E+5

10.3 . 1.000 1.000 2.3725E+5

11.1 . . 1.000 3.6500E+5

11.2 . . 1.000 5.6575E+5

11.3 . 1.000 1.000 2.3725E+5

12.1 . . 1.000 3.6500E+5

12.2 . . 1.000 5.6575E+5

12.3 . 1.000 1.000 2.3725E+5

13.1 . . 1.000 7.3000E+5

13.2 . . 1.000 1.1315E+6

13.3 . 1.000 1.000 4.7450E+5

14.1 . . 1.000 1.3742E+6

14.2 . 1.000 1.000 2.1300E+6

14.3 . . 1.000 8.9325E+5

15.1 . 1.000 1.000 6.5700E+6

15.2 . . 1.000 1.0184E+7

15.3 . . 1.000 4.2705E+6

16.1 . . 1.000 2.6280E+6

16.2 . 1.000 1.000 4.0734E+6

16.3 . . 1.000 1.7082E+6

17.1 . . 1.000 2.1389E+7

17.2 . 1.000 1.000 3.3153E+7

17.3 . . 1.000 1.3903E+7

18.1 . 1.000 1.000 8.3950E+6

18.2 . . 1.000 1.3012E+7

18.3 . . 1.000 5.4567E+6

19.1 . . 1.000 4.2048E+5

19.2 . 1.000 1.000 6.5174E+5

19.3 . . 1.000 2.7331E+5

20.1 . 1.000 1.000 1.3213E+5

20.2 . . 1.000 2.0480E+5

20.3 . . 1.000 85884.500

21.1 . 1.000 1.000 3.9420E+7

21.2 . . 1.000 6.1101E+7

21.3 . . 1.000 2.5623E+7

22.1 . . 1.000 1.7082E+6

22.2 . 1.000 1.000 2.6477E+6

22.3 . . 1.000 1.1103E+6

23.1 . 1.000 1.000 1.0253E+7

23.2 . . 1.000 1.5892E+7

23.3 . . 1.000 6.6644E+6

24.1 . 1.000 1.000 7.0117E+5

24.2 . . 1.000 1.0868E+6

24.3 . . 1.000 4.5576E+5

25.1 . 1.000 1.000 1.9856E+5

25.2 . . 1.000 3.0777E+5

25.3 . . 1.000 1.2906E+5

26.1 . 1.000 1.000 1.8250E+5

26.2 . . 1.000 2.8288E+5

26.3 . . 1.000 1.1863E+5

27.1 . . 1.000 1095.000

27.2 . . 1.000 1697.250

27.3 . 1.000 1.000 711.750

28.1 . 1.000 1.000 4.5479E+5

28.2 . . 1.000 7.0492E+5

28.3 . . 1.000 2.9561E+5

29.1 . . 1.000 19710.000

29.2 . . 1.000 30550.500

29.3 . 1.000 1.000 12811.500

LOWER LEVEL UPPER MARGINAL

---- VAR Tobj -INF 1.4800E+8 +INF .

Tobj Objective function

\*\*\*\* REPORT SUMMARY : 0 NONOPT

0 INFEASIBLE

0 UNBOUNDED

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Equation Listing SOLVE problem Using MIP From line 164

---- objective =E=

objective.. - 16826500\*b(1,1) - 26081075\*b(1,2) - 10937225\*b(1,3)

- 547500\*b(2,1) - 848625\*b(2,2) - 355875\*b(2,3) - 1679000\*b(3,1)

- 2602450\*b(3,2) - 1091350\*b(3,3) - 547500\*b(4,1) - 848625\*b(4,2)

- 355875\*b(4,3) - 730000\*b(5,1) - 1131500\*b(5,2) - 474500\*b(5,3)

- 817600\*b(6,1) - 1267280\*b(6,2) - 531440\*b(6,3) - 438000\*b(7,1)

- 678900\*b(7,2) - 284700\*b(7,3) - 9855000\*b(8,1) - 15275250\*b(8,2)

- 6405750\*b(8,3) - 1642500\*b(9,1) - 2545875\*b(9,2) - 1067625\*b(9,3)

- 365000\*b(10,1) - 565750\*b(10,2) - 237250\*b(10,3) - 365000\*b(11,1)

- 565750\*b(11,2) - 237250\*b(11,3) - 365000\*b(12,1) - 565750\*b(12,2)

- 237250\*b(12,3) - 730000\*b(13,1) - 1131500\*b(13,2) - 474500\*b(13,3)

- 1374225\*b(14,1) - 2130048.75\*b(14,2) - 893246.25\*b(14,3)

- 6570000\*b(15,1) - 10183500\*b(15,2) - 4270500\*b(15,3) - 2628000\*b(16,1)

- 4073400\*b(16,2) - 1708200\*b(16,3) - 21389000\*b(17,1) - 33152950\*b(17,2)

- 13902850\*b(17,3) - 8395000\*b(18,1) - 13012250\*b(18,2) - 5456750\*b(18,3)

- 420480\*b(19,1) - 651744\*b(19,2) - 273312\*b(19,3) - 132130\*b(20,1)

- 204801.5\*b(20,2) - 85884.5\*b(20,3) - 39420000\*b(21,1) - 61101000\*b(21,2)

- 25623000\*b(21,3) - 1708200\*b(22,1) - 2647710\*b(22,2) - 1110330\*b(22,3)

- 10252850\*b(23,1) - 15891917.5\*b(23,2) - 6664352.5\*b(23,3)

- 701165\*b(24,1) - 1086805.75\*b(24,2) - 455757.25\*b(24,3) - 198560\*b(25,1)

- 307768\*b(25,2) - 129064\*b(25,3) - 182500\*b(26,1) - 282875\*b(26,2)

- 118625\*b(26,3) - 1095\*b(27,1) - 1697.25\*b(27,2) - 711.75\*b(27,3)

- 454790\*b(28,1) - 704924.5\*b(28,2) - 295613.5\*b(28,3) - 19710\*b(29,1)

- 30550.5\*b(29,2) - 12811.5\*b(29,3) + obj =E= 0 ;

(LHS = -147997061, INFES = 147997061 \*\*\*\*)

---- c1 =L=

c1(1).. b(1,1) + b(1,2) + b(1,3) =L= 3 ; (LHS = 1)

c1(2).. b(2,1) + b(2,2) + b(2,3) =L= 3 ; (LHS = 1)

c1(3).. b(3,1) + b(3,2) + b(3,3) =L= 3 ; (LHS = 1)

REMAINING 26 ENTRIES SKIPPED

---- c3 =E=

c3(1).. t(1,1) =E= 0 ; (LHS = 0)

c3(2).. t(2,2) =E= 0 ; (LHS = 0)

c3(3).. t(3,3) =E= 0 ; (LHS = 0)

REMAINING 26 ENTRIES SKIPPED

---- c4 =G=

c4(1).. 0.1273597785\*b(1,1) + 0.19103966775\*b(1,2) + 0.0636798892499999\*b(1,3)

- 0.1\*t(1,1) + t(1,2) + t(1,3) + t(1,4) + t(1,5) + t(1,6) + t(1,7)

+ t(1,8) + t(1,9) + t(1,10) + t(1,11) + t(1,12) + t(1,13) + t(1,14)

+ t(1,15) + t(1,16) + t(1,17) + t(1,18) + t(1,19) + t(1,20) + t(1,21)

+ t(1,22) + t(1,23) + t(1,24) + t(1,25) + t(1,26) + t(1,27) + t(1,28)

+ t(1,29) - 1.1\*t(2,1) - 1.1\*t(3,1) - 1.1\*t(4,1) - 1.1\*t(5,1) - 1.1\*t(6,1)

- 1.1\*t(7,1) - 1.1\*t(8,1) - 1.1\*t(9,1) - 1.1\*t(10,1) - 1.1\*t(11,1)

- 1.1\*t(12,1) - 1.1\*t(13,1) - 1.1\*t(14,1) - 1.1\*t(15,1) - 1.1\*t(16,1)

- 1.1\*t(17,1) - 1.1\*t(18,1) - 1.1\*t(19,1) - 1.1\*t(20,1) - 1.1\*t(21,1)

- 1.1\*t(22,1) - 1.1\*t(23,1) - 1.1\*t(24,1) - 1.1\*t(25,1) - 1.1\*t(26,1)

- 1.1\*t(27,1) - 1.1\*t(28,1) - 1.1\*t(29,1) =G= 0.122832874808418 ;

(LHS = 0.1273597785)

c4(2).. 0.00414402749999999\*b(2,1) + 0.00621604124999999\*b(2,2)

+ 0.00207201375\*b(2,3) - 1.1\*t(1,2) + t(2,1) - 0.1\*t(2,2) + t(2,3)

+ t(2,4) + t(2,5) + t(2,6) + t(2,7) + t(2,8) + t(2,9) + t(2,10) + t(2,11)

+ t(2,12) + t(2,13) + t(2,14) + t(2,15) + t(2,16) + t(2,17) + t(2,18)

+ t(2,19) + t(2,20) + t(2,21) + t(2,22) + t(2,23) + t(2,24) + t(2,25)

+ t(2,26) + t(2,27) + t(2,28) + t(2,29) - 1.1\*t(3,2) - 1.1\*t(4,2)

- 1.1\*t(5,2) - 1.1\*t(6,2) - 1.1\*t(7,2) - 1.1\*t(8,2) - 1.1\*t(9,2)

- 1.1\*t(10,2) - 1.1\*t(11,2) - 1.1\*t(12,2) - 1.1\*t(13,2) - 1.1\*t(14,2)

- 1.1\*t(15,2) - 1.1\*t(16,2) - 1.1\*t(17,2) - 1.1\*t(18,2) - 1.1\*t(19,2)

- 1.1\*t(20,2) - 1.1\*t(21,2) - 1.1\*t(22,2) - 1.1\*t(23,2) - 1.1\*t(24,2)

- 1.1\*t(25,2) - 1.1\*t(26,2) - 1.1\*t(27,2) - 1.1\*t(28,2) - 1.1\*t(29,2) =G=

0.00202831822193877 ; (LHS = 0.00207201375)

c4(3).. 0.012708351\*b(3,1) + 0.0190625265\*b(3,2) + 0.00635417549999999\*b(3,3)

- 1.1\*t(1,3) - 1.1\*t(2,3) + t(3,1) + t(3,2) - 0.1\*t(3,3) + t(3,4) + t(3,5)

+ t(3,6) + t(3,7) + t(3,8) + t(3,9) + t(3,10) + t(3,11) + t(3,12)

+ t(3,13) + t(3,14) + t(3,15) + t(3,16) + t(3,17) + t(3,18) + t(3,19)

+ t(3,20) + t(3,21) + t(3,22) + t(3,23) + t(3,24) + t(3,25) + t(3,26)

+ t(3,27) + t(3,28) + t(3,29) - 1.1\*t(4,3) - 1.1\*t(5,3) - 1.1\*t(6,3)

- 1.1\*t(7,3) - 1.1\*t(8,3) - 1.1\*t(9,3) - 1.1\*t(10,3) - 1.1\*t(11,3)

- 1.1\*t(12,3) - 1.1\*t(13,3) - 1.1\*t(14,3) - 1.1\*t(15,3) - 1.1\*t(16,3)

- 1.1\*t(17,3) - 1.1\*t(18,3) - 1.1\*t(19,3) - 1.1\*t(20,3) - 1.1\*t(21,3)

- 1.1\*t(22,3) - 1.1\*t(23,3) - 1.1\*t(24,3) - 1.1\*t(25,3) - 1.1\*t(26,3)

- 1.1\*t(27,3) - 1.1\*t(28,3) - 1.1\*t(29,3) =G= 0.0100326811806122 ;

(LHS = 0.012708351)

REMAINING 26 ENTRIES SKIPPED

---- c5 =G=

c5(1).. - 16826500\*b(1,1) - 26081075\*b(1,2) - 10937225\*b(1,3) =G= -16826500 ;

(LHS = -16826500)

c5(2).. - 547500\*b(2,1) - 848625\*b(2,2) - 355875\*b(2,3) =G= -355875 ;

(LHS = -355875)

c5(3).. - 1679000\*b(3,1) - 2602450\*b(3,2) - 1091350\*b(3,3) =G= -1679000 ;

(LHS = -1679000)

REMAINING 26 ENTRIES SKIPPED

---- c6 =G=

c6(1).. 0.1273597785\*b(1,1) + 0.19103966775\*b(1,2) + 0.0636798892499999\*b(1,3)

- 0.1\*t(1,1) + t(1,2) + t(1,3) + t(1,4) + t(1,5) + t(1,6) + t(1,7)

+ t(1,8) + t(1,9) + t(1,10) + t(1,11) + t(1,12) + t(1,13) + t(1,14)

+ t(1,15) + t(1,16) + t(1,17) + t(1,18) + t(1,19) + t(1,20) + t(1,21)

+ t(1,22) + t(1,23) + t(1,24) + t(1,25) + t(1,26) + t(1,27) + t(1,28)

+ t(1,29) - 1.1\*t(2,1) - 1.1\*t(3,1) - 1.1\*t(4,1) - 1.1\*t(5,1) - 1.1\*t(6,1)

- 1.1\*t(7,1) - 1.1\*t(8,1) - 1.1\*t(9,1) - 1.1\*t(10,1) - 1.1\*t(11,1)

- 1.1\*t(12,1) - 1.1\*t(13,1) - 1.1\*t(14,1) - 1.1\*t(15,1) - 1.1\*t(16,1)

- 1.1\*t(17,1) - 1.1\*t(18,1) - 1.1\*t(19,1) - 1.1\*t(20,1) - 1.1\*t(21,1)

- 1.1\*t(22,1) - 1.1\*t(23,1) - 1.1\*t(24,1) - 1.1\*t(25,1) - 1.1\*t(26,1)

- 1.1\*t(27,1) - 1.1\*t(28,1) - 1.1\*t(29,1) =G= 0 ; (LHS = 0.1273597785)

c6(2).. 0.00414402749999999\*b(2,1) + 0.00621604124999999\*b(2,2)

+ 0.00207201375\*b(2,3) - 1.1\*t(1,2) + t(2,1) - 0.1\*t(2,2) + t(2,3)

+ t(2,4) + t(2,5) + t(2,6) + t(2,7) + t(2,8) + t(2,9) + t(2,10) + t(2,11)

+ t(2,12) + t(2,13) + t(2,14) + t(2,15) + t(2,16) + t(2,17) + t(2,18)

+ t(2,19) + t(2,20) + t(2,21) + t(2,22) + t(2,23) + t(2,24) + t(2,25)

+ t(2,26) + t(2,27) + t(2,28) + t(2,29) - 1.1\*t(3,2) - 1.1\*t(4,2)

- 1.1\*t(5,2) - 1.1\*t(6,2) - 1.1\*t(7,2) - 1.1\*t(8,2) - 1.1\*t(9,2)

- 1.1\*t(10,2) - 1.1\*t(11,2) - 1.1\*t(12,2) - 1.1\*t(13,2) - 1.1\*t(14,2)

- 1.1\*t(15,2) - 1.1\*t(16,2) - 1.1\*t(17,2) - 1.1\*t(18,2) - 1.1\*t(19,2)

- 1.1\*t(20,2) - 1.1\*t(21,2) - 1.1\*t(22,2) - 1.1\*t(23,2) - 1.1\*t(24,2)

- 1.1\*t(25,2) - 1.1\*t(26,2) - 1.1\*t(27,2) - 1.1\*t(28,2) - 1.1\*t(29,2) =G=

0 ; (LHS = 0.00207201375)

c6(3).. 0.012708351\*b(3,1) + 0.0190625265\*b(3,2) + 0.00635417549999999\*b(3,3)

- 1.1\*t(1,3) - 1.1\*t(2,3) + t(3,1) + t(3,2) - 0.1\*t(3,3) + t(3,4) + t(3,5)

+ t(3,6) + t(3,7) + t(3,8) + t(3,9) + t(3,10) + t(3,11) + t(3,12)

+ t(3,13) + t(3,14) + t(3,15) + t(3,16) + t(3,17) + t(3,18) + t(3,19)

+ t(3,20) + t(3,21) + t(3,22) + t(3,23) + t(3,24) + t(3,25) + t(3,26)

+ t(3,27) + t(3,28) + t(3,29) - 1.1\*t(4,3) - 1.1\*t(5,3) - 1.1\*t(6,3)

- 1.1\*t(7,3) - 1.1\*t(8,3) - 1.1\*t(9,3) - 1.1\*t(10,3) - 1.1\*t(11,3)

- 1.1\*t(12,3) - 1.1\*t(13,3) - 1.1\*t(14,3) - 1.1\*t(15,3) - 1.1\*t(16,3)

- 1.1\*t(17,3) - 1.1\*t(18,3) - 1.1\*t(19,3) - 1.1\*t(20,3) - 1.1\*t(21,3)

- 1.1\*t(22,3) - 1.1\*t(23,3) - 1.1\*t(24,3) - 1.1\*t(25,3) - 1.1\*t(26,3)

- 1.1\*t(27,3) - 1.1\*t(28,3) - 1.1\*t(29,3) =G= 0 ; (LHS = 0.012708351)

REMAINING 26 ENTRIES SKIPPED

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Column Listing SOLVE problem Using MIP From line 164

---- b binary variable specifying the process selection

b(1,1)

(.LO, .L, .UP, .M = 0, 1, 1, 16826500)

-1.682650E+7 objective

1 c1(1)

0.1274 c4(1)

-1.682650E+7 c5(1)

0.1274 c6(1)

b(1,2)

(.LO, .L, .UP, .M = 0, 0, 1, 26081075)

-2.608108E+7 objective

1 c1(1)

0.191 c4(1)

-2.608108E+7 c5(1)

0.191 c6(1)

b(1,3)

(.LO, .L, .UP, .M = 0, 0, 1, 10937225)

-1.093723E+7 objective

1 c1(1)

0.0637 c4(1)

-1.093723E+7 c5(1)

0.0637 c6(1)

REMAINING 84 ENTRIES SKIPPED

---- t Variable deciding the amount of mercury traded between various industrie

s

t(1,1)

(.LO, .L, .UP, .M = 0, 0, +INF, 0)

1 c3(1)

-0.1 c4(1)

-0.1 c6(1)

t(1,2)

(.LO, .L, .UP, .M = 0, 0, +INF, 0)

1 c4(1)

-1.1 c4(2)

1 c6(1)

-1.1 c6(2)

t(1,3)

(.LO, .L, .UP, .M = 0, 0, +INF, 0)

1 c4(1)

-1.1 c4(3)

1 c6(1)

-1.1 c6(3)

REMAINING 838 ENTRIES SKIPPED

---- obj Objective function

obj

(.LO, .L, .UP, .M = -INF, 0, +INF, 0)

1 objective

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Model Statistics SOLVE problem Using MIP From line 164

MODEL STATISTICS

BLOCKS OF EQUATIONS 6 SINGLE EQUATIONS 146

BLOCKS OF VARIABLES 3 SINGLE VARIABLES 929

NON ZERO ELEMENTS 3,771 DISCRETE VARIABLES 87

GENERATION TIME = 0.016 SECONDS 3 MB 24.1.3 r41464 WEX-WEI

EXECUTION TIME = 0.016 SECONDS 3 MB 24.1.3 r41464 WEX-WEI

GAMS 24.1.3 r41464 Released Jul 26, 2013 WEX-WEI x86\_64/MS Windows 01/19/16 16:18:25 Page 9

G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

Solution Report SOLVE problem Using MIP From line 164

S O L V E S U M M A R Y

MODEL problem OBJECTIVE obj

TYPE MIP DIRECTION MINIMIZE

SOLVER CPLEX FROM LINE 164

\*\*\*\* SOLVER STATUS 1 Normal Completion

\*\*\*\* MODEL STATUS 8 Integer Solution

\*\*\*\* OBJECTIVE VALUE 121119045.0000

RESOURCE USAGE, LIMIT 0.359 1000.000

ITERATION COUNT, LIMIT 321 2000000000

IBM ILOG CPLEX 24.1.3 r41464 Released Jul 26, 2013 WEI x86\_64/MS Windows

--- GAMS/Cplex licensed for continuous and discrete problems.

Cplex 12.5.1.0

MIP status(102): integer optimal, tolerance

Cplex Time: 0.27sec (det. 28.04 ticks)

Fixing integer variables, and solving final LP...

Fixed MIP status(1): optimal

Cplex Time: 0.02sec (det. 1.44 ticks)

Solution satisfies tolerances.

MIP Solution: 121119045.000000 (255 iterations, 10 nodes)

Final Solve: 121119045.000000 (66 iterations)

Best possible: 121006521.186057

Absolute gap: 112523.813943

Relative gap: 0.000929

LOWER LEVEL UPPER MARGINAL

---- EQU objective . . . 1.000

---- EQU c1

LOWER LEVEL UPPER MARGINAL

1 -INF 1.000 3.000 .

2 -INF . 3.000 .

3 -INF . 3.000 .

4 -INF . 3.000 .

5 -INF . 3.000 .

6 -INF . 3.000 .

7 -INF . 3.000 .

8 -INF 1.000 3.000 .

9 -INF 1.000 3.000 .

10 -INF . 3.000 .

11 -INF . 3.000 .

12 -INF . 3.000 .

13 -INF . 3.000 .

14 -INF 1.000 3.000 .

15 -INF 1.000 3.000 .

16 -INF 1.000 3.000 .

17 -INF 1.000 3.000 .

18 -INF 1.000 3.000 .

19 -INF 1.000 3.000 .

20 -INF . 3.000 .

21 -INF 1.000 3.000 .

22 -INF 1.000 3.000 .

23 -INF 1.000 3.000 .

24 -INF . 3.000 .

25 -INF . 3.000 .

26 -INF 1.000 3.000 .

27 -INF . 3.000 .

28 -INF 1.000 3.000 .

29 -INF . 3.000 .

---- EQU c3

LOWER LEVEL UPPER MARGINAL

1 . . . .

2 . . . .

3 . . . .

4 . . . .

5 . . . .

6 . . . .

7 . . . .

8 . . . .

9 . . . .

10 . . . .

11 . . . .

12 . . . .

13 . . . .

14 . . . .

15 . . . .

16 . . . .

17 . . . .

18 . . . .

19 . . . .

20 . . . .

21 . . . .

22 . . . .

23 . . . .

24 . . . .

25 . . . .

26 . . . .

27 . . . .

28 . . . .

29 . . . .

---- EQU c4

LOWER LEVEL UPPER MARGINAL

1 0.123 0.123 +INF EPS

2 0.002 0.002 +INF EPS

3 0.010 0.010 +INF EPS

4 0.001 0.001 +INF EPS

5 0.003 0.003 +INF EPS

6 0.003 0.003 +INF EPS

7 0.002 0.002 +INF EPS

8 0.079 0.079 +INF EPS

9 0.008 0.008 +INF EPS

10 5.2341E-4 5.2341E-4 +INF EPS

11 4.6815E-4 4.6815E-4 +INF EPS

12 6.8917E-4 6.8917E-4 +INF EPS

13 0.002 0.002 +INF EPS

14 0.011 0.011 +INF EPS

15 0.040 0.040 +INF EPS

16 0.024 0.024 +INF EPS

17 0.174 0.174 +INF EPS

18 0.057 0.057 +INF EPS

19 0.004 0.004 +INF EPS

20 7.0952E-4 7.0952E-4 +INF EPS

21 0.277 0.277 +INF EPS

22 0.016 0.016 +INF EPS

23 0.066 0.066 +INF EPS

24 0.003 0.003 +INF EPS

25 0.001 0.001 +INF EPS

26 8.4877E-4 8.4877E-4 +INF EPS

27 4.1395E-6 4.1395E-6 +INF EPS

28 0.002 0.002 +INF EPS

29 5.0642E-5 5.0642E-5 +INF EPS

---- EQU c5

LOWER LEVEL UPPER MARGINAL

1 -1.683E+7 -1.683E+7 +INF .

2 -3.559E+5 . +INF .

3 -1.679E+6 . +INF .

4 -3.559E+5 . +INF .

5 -7.300E+5 . +INF .

6 -5.314E+5 . +INF .

7 -4.380E+5 . +INF .

8 -1.528E+7 -9.855E+6 +INF .

9 -1.642E+6 -1.642E+6 +INF .

10 -2.373E+5 . +INF .

11 -2.373E+5 . +INF .

12 -2.373E+5 . +INF .

13 -4.745E+5 . +INF .

14 -2.130E+6 -1.374E+6 +INF .

15 -6.570E+6 -6.570E+6 +INF .

16 -4.073E+6 -2.628E+6 +INF .

17 -3.315E+7 -2.139E+7 +INF .

18 -8.395E+6 -8.395E+6 +INF .

19 -6.517E+5 -4.205E+5 +INF .

20 -1.321E+5 . +INF .

21 -3.942E+7 -3.942E+7 +INF .

22 -2.648E+6 -1.708E+6 +INF .

23 -1.025E+7 -1.025E+7 +INF .

24 -7.012E+5 . +INF .

25 -1.986E+5 . +INF .

26 -1.825E+5 -1.825E+5 +INF .

27 -711.750 . +INF .

28 -4.548E+5 -4.548E+5 +INF .

29 -1.281E+4 . +INF .

---- EQU c6

LOWER LEVEL UPPER MARGINAL

1 . 0.123 +INF .

2 . 0.002 +INF .

3 . 0.010 +INF .

4 . 0.001 +INF .

5 . 0.003 +INF .

6 . 0.003 +INF .

7 . 0.002 +INF .

8 . 0.079 +INF .

9 . 0.008 +INF .

10 . 5.2341E-4 +INF .

11 . 4.6815E-4 +INF .

12 . 6.8917E-4 +INF .

13 . 0.002 +INF .

14 . 0.011 +INF .

15 . 0.040 +INF .

16 . 0.024 +INF .

17 . 0.174 +INF .

18 . 0.057 +INF .

19 . 0.004 +INF .

20 . 7.0952E-4 +INF .

21 . 0.277 +INF .

22 . 0.016 +INF .

23 . 0.066 +INF .

24 . 0.003 +INF .

25 . 0.001 +INF .

26 . 8.4877E-4 +INF .

27 . 4.1395E-6 +INF .

28 . 0.002 +INF .

29 . 5.0642E-5 +INF .

---- VAR b binary variable specifying the process selection

LOWER LEVEL UPPER MARGINAL

1 .1 . 1.000 1.000 1.6827E+7

1 .2 . . 1.000 2.6081E+7

1 .3 . . 1.000 1.0937E+7

2 .1 . . 1.000 5.4750E+5

2 .2 . . 1.000 8.4863E+5

2 .3 . . 1.000 3.5588E+5

3 .1 . . 1.000 1.6790E+6

3 .2 . . 1.000 2.6025E+6

3 .3 . . 1.000 1.0913E+6

4 .1 . . 1.000 5.4750E+5

4 .2 . . 1.000 8.4863E+5

4 .3 . . 1.000 3.5588E+5

5 .1 . . 1.000 7.3000E+5

5 .2 . . 1.000 1.1315E+6

5 .3 . . 1.000 4.7450E+5

6 .1 . . 1.000 8.1760E+5

6 .2 . . 1.000 1.2673E+6

6 .3 . . 1.000 5.3144E+5

7 .1 . . 1.000 4.3800E+5

7 .2 . . 1.000 6.7890E+5

7 .3 . . 1.000 2.8470E+5

8 .1 . 1.000 1.000 9.8550E+6

8 .2 . . 1.000 1.5275E+7

8 .3 . . 1.000 6.4058E+6

9 .1 . 1.000 1.000 1.6425E+6

9 .2 . . 1.000 2.5459E+6

9 .3 . . 1.000 1.0676E+6

10.1 . . 1.000 3.6500E+5

10.2 . . 1.000 5.6575E+5

10.3 . . 1.000 2.3725E+5

11.1 . . 1.000 3.6500E+5

11.2 . . 1.000 5.6575E+5

11.3 . . 1.000 2.3725E+5

12.1 . . 1.000 3.6500E+5

12.2 . . 1.000 5.6575E+5

12.3 . . 1.000 2.3725E+5

13.1 . . 1.000 7.3000E+5

13.2 . . 1.000 1.1315E+6

13.3 . . 1.000 4.7450E+5

14.1 . 1.000 1.000 1.3742E+6

14.2 . . 1.000 2.1300E+6

14.3 . . 1.000 8.9325E+5

15.1 . 1.000 1.000 6.5700E+6

15.2 . . 1.000 1.0184E+7

15.3 . . 1.000 4.2705E+6

16.1 . 1.000 1.000 2.6280E+6

16.2 . . 1.000 4.0734E+6

16.3 . . 1.000 1.7082E+6

17.1 . 1.000 1.000 2.1389E+7

17.2 . . 1.000 3.3153E+7

17.3 . . 1.000 1.3903E+7

18.1 . 1.000 1.000 8.3950E+6

18.2 . . 1.000 1.3012E+7

18.3 . . 1.000 5.4567E+6

19.1 . 1.000 1.000 4.2048E+5

19.2 . . 1.000 6.5174E+5

19.3 . . 1.000 2.7331E+5

20.1 . . 1.000 1.3213E+5

20.2 . . 1.000 2.0480E+5

20.3 . . 1.000 85884.500

21.1 . 1.000 1.000 3.9420E+7

21.2 . . 1.000 6.1101E+7

21.3 . . 1.000 2.5623E+7

22.1 . 1.000 1.000 1.7082E+6

22.2 . . 1.000 2.6477E+6

22.3 . . 1.000 1.1103E+6

23.1 . 1.000 1.000 1.0253E+7

23.2 . . 1.000 1.5892E+7

23.3 . . 1.000 6.6644E+6

24.1 . . 1.000 7.0117E+5

24.2 . . 1.000 1.0868E+6

24.3 . . 1.000 4.5576E+5

25.1 . . 1.000 1.9856E+5

25.2 . . 1.000 3.0777E+5

25.3 . . 1.000 1.2906E+5

26.1 . 1.000 1.000 1.8250E+5

26.2 . . 1.000 2.8288E+5

26.3 . . 1.000 1.1863E+5

27.1 . . 1.000 1095.000

27.2 . . 1.000 1697.250

27.3 . . 1.000 711.750

28.1 . 1.000 1.000 4.5479E+5

28.2 . . 1.000 7.0492E+5

28.3 . . 1.000 2.9561E+5

29.1 . . 1.000 19710.000

29.2 . . 1.000 30550.500

29.3 . . 1.000 12811.500

---- VAR t Variable deciding the amount of mercury traded between various indus

tries

LOWER LEVEL UPPER MARGINAL

1 .1 . . +INF EPS

1 .2 . . +INF EPS

1 .3 . . +INF EPS

1 .4 . . +INF EPS

1 .5 . . +INF EPS

1 .6 . . +INF EPS

1 .7 . . +INF EPS

1 .8 . . +INF EPS

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1 .15 . . +INF EPS

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1 .19 . . +INF EPS

1 .20 . . +INF EPS

1 .21 . 0.003 +INF .

1 .22 . . +INF EPS

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1 .28 . . +INF EPS

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2 .7 . . +INF EPS

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2 .18 . . +INF EPS

2 .19 . . +INF EPS

2 .20 . . +INF EPS

2 .21 . 0.002 +INF .

2 .22 . . +INF EPS

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3 .1 . . +INF EPS

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3 .13 . . +INF EPS

3 .14 . . +INF EPS

3 .15 . 0.001 +INF .

3 .16 . . +INF EPS

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3 .19 . . +INF EPS

3 .20 . . +INF EPS

3 .21 . 0.009 +INF .

3 .22 . . +INF EPS

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4 .18 . 0.001 +INF .

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5 .1 . 0.003 +INF .

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5 .25 . . +INF EPS

5 .26 . 7.3754E-5 +INF .

5 .27 . . +INF EPS

5 .28 . . +INF EPS

5 .29 . . +INF EPS

6 .1 . . +INF EPS

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7 .10 . . +INF EPS

7 .11 . . +INF EPS

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7 .14 . . +INF EPS

7 .15 . 5.8189E-4 +INF .

7 .16 . . +INF EPS

7 .17 . . +INF EPS

7 .18 . 0.001 +INF .

7 .19 . . +INF EPS

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10.23 . 5.2341E-4 +INF .

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11.1 . 4.6815E-4 +INF .

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12.1 . 6.8917E-4 +INF .

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13.9 . 0.002 +INF .

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14.26 . 4.1040E-4 +INF .

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16.1 . 9.5129E-4 +INF .

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17.1 . 6.3202E-4 +INF .

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17.23 . 0.010 +INF .

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17.28 . 9.7181E-4 +INF .

17.29 . . +INF EPS

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19.1 . 5.2340E-4 +INF .

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20.1 . 7.0952E-4 +INF .

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22.9 . 0.002 +INF .

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22.21 . 6.4816E-4 +INF .

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23.20 . . +INF EPS

23.21 . . +INF EPS

23.22 . . +INF EPS

23.23 . . +INF EPS

23.24 . . +INF EPS

23.25 . . +INF EPS

23.26 . . +INF EPS

23.27 . . +INF EPS

23.28 . . +INF EPS

23.29 . . +INF EPS

24.1 . . +INF EPS

24.2 . . +INF EPS

24.3 . . +INF EPS

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24.6 . . +INF EPS

24.7 . . +INF EPS

24.8 . . +INF EPS

24.9 . . +INF EPS

24.10 . . +INF EPS

24.11 . . +INF EPS

24.12 . . +INF EPS

24.13 . . +INF EPS

24.14 . . +INF EPS

24.15 . . +INF EPS

24.16 . . +INF EPS

24.17 . . +INF EPS

24.18 . . +INF EPS

24.19 . . +INF EPS

24.20 . . +INF EPS

24.21 . 0.003 +INF .

24.22 . . +INF EPS

24.23 . . +INF EPS

24.24 . . +INF EPS

24.25 . . +INF EPS

24.26 . . +INF EPS

24.27 . . +INF EPS

24.28 . . +INF EPS

24.29 . . +INF EPS

25.1 . . +INF EPS

25.2 . . +INF EPS

25.3 . . +INF EPS

25.4 . . +INF EPS

25.5 . . +INF EPS

25.6 . . +INF EPS

25.7 . . +INF EPS

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25.11 . . +INF EPS

25.12 . . +INF EPS

25.13 . . +INF EPS

25.14 . . +INF EPS

25.15 . . +INF EPS

25.16 . . +INF EPS

25.17 . . +INF EPS

25.18 . . +INF EPS

25.19 . . +INF EPS

25.20 . . +INF EPS

25.21 . 0.001 +INF .

25.22 . . +INF EPS

25.23 . . +INF EPS

25.24 . . +INF EPS

25.25 . . +INF EPS

25.26 . . +INF EPS

25.27 . . +INF EPS

25.28 . . +INF EPS

25.29 . . +INF EPS

26.1 . . +INF EPS

26.2 . . +INF EPS

26.3 . . +INF EPS

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26.27 . . +INF EPS

26.28 . . +INF EPS

26.29 . . +INF EPS

27.1 . . +INF EPS

27.2 . . +INF EPS

27.3 . . +INF EPS

27.4 . . +INF EPS

27.5 . . +INF EPS

27.6 . . +INF EPS

27.7 . . +INF EPS

27.8 . . +INF EPS

27.9 . . +INF EPS

27.10 . . +INF EPS

27.11 . . +INF EPS

27.12 . . +INF EPS

27.13 . . +INF EPS

27.14 . . +INF EPS

27.15 . 4.1395E-6 +INF .

27.16 . . +INF EPS

27.17 . . +INF EPS

27.18 . . +INF EPS

27.19 . . +INF EPS

27.20 . . +INF EPS

27.21 . . +INF EPS

27.22 . . +INF EPS

27.23 . . +INF EPS

27.24 . . +INF EPS

27.25 . . +INF EPS

27.26 . . +INF EPS

27.27 . . +INF EPS

27.28 . . +INF EPS

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28.1 . . +INF EPS

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28.18 . . +INF EPS

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28.27 . . +INF EPS

28.28 . . +INF EPS

28.29 . . +INF EPS

29.1 . . +INF EPS

29.2 . . +INF EPS

29.3 . . +INF EPS

29.4 . . +INF EPS

29.5 . . +INF EPS

29.6 . . +INF EPS

29.7 . . +INF EPS

29.8 . . +INF EPS

29.9 . . +INF EPS

29.10 . . +INF EPS

29.11 . . +INF EPS

29.12 . . +INF EPS

29.13 . . +INF EPS

29.14 . . +INF EPS

29.15 . . +INF EPS

29.16 . . +INF EPS

29.17 . . +INF EPS

29.18 . . +INF EPS

29.19 . . +INF EPS

29.20 . . +INF EPS

29.21 . 5.0642E-5 +INF .

29.22 . . +INF EPS

29.23 . . +INF EPS

29.24 . . +INF EPS

29.25 . . +INF EPS

29.26 . . +INF EPS

29.27 . . +INF EPS

29.28 . . +INF EPS

29.29 . . +INF EPS

LOWER LEVEL UPPER MARGINAL

---- VAR obj -INF 1.2112E+8 +INF .

obj Objective function

\*\*\*\* REPORT SUMMARY : 0 NONOPT

0 INFEASIBLE

0 UNBOUNDED

GAMS 24.1.3 r41464 Released Jul 26, 2013 WEX-WEI x86\_64/MS Windows 01/19/16 16:18:25 Page 10

G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m

E x e c u t i o n

---- 205 PARAMETER WQS = 2.721 Water Quality Standar

d (ng per lit)

---- 205 PARAMETER red\_final Final reduction in the discharge achieved by ea

ch industry after optimization

1

1 0.123

2 0.002

3 0.010

4 0.001

5 0.003

6 0.003

7 0.002

8 0.079

9 0.008

10 5.234066E-4

11 4.681529E-4

12 6.891677E-4

13 0.002

14 0.011

15 0.040

16 0.024

17 0.174

18 0.057

19 0.004

20 7.095210E-4

21 0.277

22 0.016

23 0.066

24 0.003

25 0.001

26 8.487739E-4

27 4.139517E-6

28 0.002

29 5.064171E-5

---- 205 PARAMETER WQS\_final Final water standard achieved after reduction

1

1 2.721

2 2.721

3 2.721

4 2.721

5 2.721

6 2.721

7 2.721

8 2.721

9 2.721

10 2.721

11 2.721

12 2.721

13 2.721

14 2.721

15 2.721

16 2.721

17 2.721

18 2.721

19 2.721

20 2.721

21 2.721

22 2.721

23 2.721

24 2.721

25 2.721

26 2.721

27 2.721

28 2.721

29 2.721

---- 205 VARIABLE b.L binary variable specifying the process selection

1

1 1.000

8 1.000

9 1.000

14 1.000

15 1.000

16 1.000

17 1.000

18 1.000

19 1.000

21 1.000

22 1.000

23 1.000

26 1.000

28 1.000

---- 205 PARAMETER Results To store and display the final results

1 2 3 4 5

1 0.911 4.859086E+7 1.211190E+8 1.697099E+8 0.057

---- 205 PARAMETER cost cost incurred by each industry due to waste treatmen

t setup

1

1 1.682497E+7

2 811.327

3 4013.072

4 562.686

5 1280.683

6 1211.582

7 781.671

8 9856624.797

9 1640870.067

10 209.363

11 187.261

12 275.667

13 650.791

14 1374389.160

15 6566463.968

16 2629507.411

17 2.139382E+7

18 8392676.816

19 420689.360

20 283.808

21 3.941235E+7

22 1709438.405

23 1.024846E+7

24 1251.325

25 534.705

26 182306.339

27 1.656

28 454401.277

29 20.257

---- 205 VARIABLE t.L Variable deciding the amount of mercury traded between

various industries

1 9 15 18 21 23

1 0.003

2 0.002

3 0.001 0.009

4 0.001

5 0.003

6 0.003

7 5.818860E-4 0.001

8 0.004

10 5.234066E-4

11 4.681529E-4

12 6.891677E-4

13 0.002

16 9.512900E-4 0.003

17 6.320167E-4 0.010

19 5.233991E-4

20 7.095210E-4

22 0.002 6.481563E-4

24 0.003

25 0.001

27 4.139517E-6

29 5.064171E-5

+ 26 28

5 7.375361E-5

14 4.103997E-4

17 9.718073E-4

EXECUTION TIME = 0.000 SECONDS 3 MB 24.1.3 r41464 WEX-WEI

USER: Jeff Polasek G130903:1641AS-WIN

Texas A&M University, Artie McFerrin Department of ChemicaDC10525

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\*\*\*\* FILE SUMMARY

Input C:\Users\debalinasengupta\Desktop\Trading\_Basic.gms

Output C:\Users\debalinasengupta\Documents\gamsdir\projdir\Trading\_Basic.lst