APPENDIX 3. DESCRIPTION OF THE MODELING SYSTEM FOR PLANNING ZONE MANAGEMENT PROBLEMS

Contents

1. Description of the Planning Zone Algorithm and Reference Data

The objects and corresponding processes described in Chapter 3 and arranged into a model using the GAMS language is a mathematical model of a planning zone. The primary task at this stage is to develop a universal structure enabling us to give uniform descriptions of various planning zones in the Syrdarya basin proceeding from the existing information and with regard to information growth in the nearest future. The description of algorithms is based on the GAMS modeling language using the WARMIS database for the Fergana planning zone as an example.

The difference between the operating systems of GAMS and WARMIS does not allow us to use identifiers of water facilities of the WARMIS database directly in the GAMS model. Therefore, informational adjustment requires code translation tables between GAMS and WARMIS.

Naturally, this code translation should be strictly coordinated with the River component, therefore, in this report we consider identifiers of flows on the contour of the planning zone model only in terms of their formal compliance. The algorithm for the planning zone model is written in the GAMS language in the form of sets and corresponding parameters, tables and equation systems.

Sets

Inp / . . . /, = set (names) of flows coming in the planning zone,

Out / . . . /, = set (names) of flows going out of the planning zone,

Pinp /n, areaN, areaB, qMAX, energyQ, priceQ/, – features of incoming flows,

where: n – reduced efficiency of irrigation facilities,

areaN = net irrigated area (ha),

areaB = gross irrigated area (ha),

qMAX = maximum carrying capacity of the system of canals,

energyQ = electric power needed to supply water (kW/m^3),

priceQ = price of 1 cu m of water,

Pout / qd, areaDN, areaDB, energyD /, = features of outgoing flows,

where: qd = drainage module m^3/day from 1 ha,

areaDN = drained area (ha),

areaDB = area of collector and drainage flow formation (ha)

energyD = electric power needed to drain water (kW/m^3),

q / w, s / = features of water resources,

where: w = water volume (m^3)

s = water salinity (g/l),

t / oct nov dec jan feb mar apr may jun jul aug sep / - time,

Lgw /LeveL1 * LeveL6/ - ranking ,

Parea /f, m, kf, hg, s0, s1, s2, s3/ = features of irrigated area,

where :f = irrigated area (ha),

m = coefficient of soil porosity ,

kf = coefficient of soil filtration (m/day) ,

hg = average depth of ground water occurrence (m),

s0, s1, s2, s3 = bar chart of degrees of soil salinity (%)

Sarea(parea) /s0, s1, s2, s3/ = ranking salinity of irrigated areas,

r / cotton, wheat, void/ = set of crops in the planning zone,

pr / area, vol, price, water_N / = features of each crop, where: area = area under a crop (ha),

vol = yield of a crop (t/ha),

price = unit price ($/t),

water_N = water consumption by each crop during the growing season,

water Crop /w0, w1, w2, w3, w4/ = ranking conditions of water shortage,

tveg(r,t) = growing periods of different crops,

Below is given an example of assigning the set tveg(r,t) for selected crops of the Fergana planning zone:

```
/ cotton   . (jun,   jul,   aug )
  wheat    . (may,   jun )
  lucerne  . (may,   jun,  jul,   aug,  sep)
  gardens  . (may,   jun,  jul,   aug,  sep)
  others   .  (may,   jun,  jul,   aug,  sep) /;
```

Parameters and Tables

Parameters tday(t) /oct 31, nov 30, dec 31, jan 31, feb 28, mar 31,

apr 30, may 31, jun 30, jul 31, aug 31, sep 30/; = number of days in each element of the set **t**,

s_scale(sarea) /s0 = 0.0, s1 = 5.0, s2 = 15.0, s3 = 30.0/ = scale of soil salinity in accordance with a WARMIS database.

w_scale(waterCrop) /w0 = 0.5, w1 = 0.6, w2 = 0.7, w3 = 0.8, w4 = 0.9/ = scale of water restraining of crops as per studies of SANIIRI.

Table Ir_sys(inp, pinp) – assigning irrigated areas in the planning zone

	n	areaN	areaB	qMAX	energyQ	priceQ
inp_name1	0.64	60000	66000	80	0	0.001
inp_name2	0.67	88000	97000	110	0	0.001

inp_name3	0.61	52000	58000	70	0	0.0
inp_L	0.62	120000	132000	160	0	0.0005
inp_E	1.00	300000	333000	100	0	0.0 ;

Table Dr_sys(out, pout) – assigning drainage systems

	qd	areaDN	areaDB	energyD
SokhIsfara	0.12	34210	50310	0
MNS_sum	0.10	20549	30220	0
Pishkoran	0.12	26955	39640	0
Achikul	0.11	84639	124470	0
SarydjugaS	0.11	69781	102620	0
Tributar_s	0.12	9159	13470	0 ;

Table area(Lgw, parea) – assigning irrigated area,

	f	m	kf	hg	s0	s1	s2	s3
LeveL1	1630	0.49	0.36	1.0	0.40	0.49	0.09	0.02
LeveL2	20210	0.49	0.36	1.5	0.40	0.49	0.09	0.02
LeveL3	102600	0.49	0.36	2.0	0.40	0.49	0.09	0.02
LeveL4	114290	0.49	0.36	3.0	0.40	0.49	0.09	0.02
LeveL5	61950	0.49	0.36	5.0	0.40	0.49	0.09	0.02
LeveL6	50970	0.49	0.36	25.0	0.40	0.49	0.09	0.02 ;

Table w_stress(r, waterCrop) – stress from water shortage

	w0	w1	w2	w3	w4
cotton	0.700	0.493	0.328	0.162	0.039
wheat	0.980	0.630	0.379	0.190	0.044
lucerne	0.980	0.641	0.467	0.221	0.081
gardens	0.880	0.566	0.343	0.175	0.042
others	0.880	0.566	0.343	0.175	0.042
void	1.000	1.000	1.000	1.000	1.000 ;

Table s_stress(r, sarea) – stress from salinity surplus

	s0	s1	s2	s3
cotton	1.0	0.7	0.3	0.0
wheat	1.0	0.6	0.3	0.0
lucerne	1.0	0.8	0.4	0.0

gardens	1.0	0.8	0.2	0.0
others	1.0	0.7	0.3	0.0
void	1.0	1.0	1.0	1.0 ;

Table crop(r, pr) –features of crops

	area	vol	price	water_N
cotton	128610	4.4	450	5270
wheat	53020	5.7	90	2780
lucerne	33790	25.6	10	8440
gardens	27880	10.1	200	5950
others	74000	38.9	50	3000
void	33000	0.0	0	0 ;

Table w_ET(r,t) = evapotranspiration of crops

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
cotton	2.24	0.36	0.0	0.0	0.0	0.0	1.18	3.91	8.53	8.09	6.49	4.57
wheat	0.0	0.0	0.0	0.0	0.0	0.7	2.53	2.89	2.77	2.57	2.53	2.46
lucerne	1.28	0.21	0.0	0.0	0.0	0.0	0.71	3.13	5.87	6.07	5.19	3.35
gardens	1.6	0.7	0.3	0.3	0.6	1.0	2.4	3.9	5.3	5.1	4.3	3.0
others	1.6	0.7	0.3	0.3	0.6	1.0	2.4	3.9	5.3	5.1	4.3	3.0
void	1.6	0.7	0.3	0.3	0.6	1.0	2.4	3.9	5.3	5.1	4.3	3.0 ;

Table w_norma(r,t) – water consumption rate including volumes for washing

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
cotton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1300	2000	0.0	1970	0.0
wheat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1470	1310	0.0	0.0	0.0
lucerne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1500	1700	1740	1800	1700
gardens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1100	1200	1250	1200	1200
others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1100	1200	1250	1200	1200
void	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 ;

Table q_inp(inp,t) = water inflow to the planning zone (volumes)

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
inp_name1	14.7	15.3	16.7	16.2	17.2	17.8	19.2	18.3	18.0	15.0	14.5	12.4
inp_name2	70.2	70.6	78.0	85.0	91.9	99.9	102.7	171.7	220.2	213.7	198.6	63.2
inp_name3	32.4	33.2	32.3	37.1	42.8	51.9	61.4	71.2	76.1	72.5	52.6	42.5

inp_L	129.6	85.5	104.4	156.9	109.5	92.1	74.3	172.7	333.9	483.5	402.3	230.2
inp_E	3.5	56.0	42.0	35.0	17.5	38.5	52.5	84.0	35.0	7.0	3.5	5.3 ;

Table s_inp(inp,t) = water inflow to the planning zone (salinity)

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
inp_name1	0.7	0.73	0.75	0.74	0.68	0.55	0.47	0.43	0.42	0.4	0.43	0.54
inp_name2	0.35	0.36	0.37	0.37	0.34	0.28	0.24	0.22	0.21	0.2	0.21	0.27
inp_name3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
inp_L	0.35	0.36	0.37	0.37	0.34	0.28	0.24	0.22	0.21	0.2	0.21	0.27
inp_E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 ;

Design Variables

We consider the layer of the aeration zone as a three-layer pie: 0-1 m is the layer where roots of plants dwell, from one meter to a critical depth, from this critical depth to the ground water level. Layers interact through flows of water and salt. Naturally, the depth of the third and the second layers may equal zero depending upon the ground water level.

2. Planning Zone GAMS Code

```
* PlanningZon.gms
$title Optimization PlanningZon
$eolcom #
* name_PZ / Fergana /,
* cod_PZ  / 1730001 /;
*---------------------------------------------------------------------*
*----------------------Water flow Planning Zon-----------------------*
*---------------------------------------------------------------------*

sets inp  / inp_name1, inp_name2, inp_name3, inp_L /,
     out  / SokhIsfara, MNS_sum, Pishkoran, Achikul, SarydjugaS, Tributar_s /;

sets inp_tr (inp) / inp_name1, inp_name2, inp_name3/,
     transfer(out) /SarydjugaS/,
     outfull(out)  / SokhIsfara, MNS_sum, Pishkoran, Achikul, Tributar_s /;

sets pinp /n, areaN, areaB, qMAX, energyQ, priceQ/,
     pout / qd, areaDN, areaDB, energyD /;

set q / w, s /;

set t / oct, nov, dec, jan, feb, mar, apr, may, jun, jul, aug, sep /;
*set tt(t) /nov, dec, jan, feb, mar, apr, may, jun, jul, aug, sep /;
parameter tday(t) /oct 31, nov 30, dec 31, jan 31, feb 28, mar 31,
```

```
                    apr 30, may 31, jun 30, jul 31, aug 31, sep 30/;

table Ir_sys(inp,pinp)
                  n      areaN      areaB      qMaX        energyQ      priceQ
*-------------------------(ga)-------(ga)----(m3/sec)------(kwt/m3)------($)--
-*
     inp_name1   0.64    60000      66000        80           0          0.001
     inp_name2   0.67    88000      97000       110           0          0.001
     inp_name3   0.61    52000      58000        70           0          0.0
     inp_L       0.62   120000     132000       160           0
0.0005;

*--------------qd = modul drenage (l/sec from 1ga)---------------*
*------------areaDN = area of drenage (ga)----------------------*
*------areaDB = area around area of drenage (ga)-----------------*
table Dr_sys(out, pout)

                       qd         areaDN     areaDB     energyD
*------------------(l/sec)ga--------ga----------ga-------kwt/m3---*
        SokhIsfara    0.12         34210      50310         0
        MNS_sum       0.10         20549      30220         0
        Pishkoran     0.12         26955      39640         0
        Achikul       0.11         84639     124470         0
        SarydjugaS    0.11         69781     102620         0
        Tributar_s    0.12          9159      13470         0  ;

set h /LeveL1 * LeveL6/;
set parea /f, m, m0, kf, hg, sg, hT, hd, s0, s1, s2, s3, s4/;
set sarea(parea) /s0, s1, s2, s3, s4/;
parameter s_scale(sarea) /s0 = 0.0, s1 = 5.0, s2 = 15.0, s3 = 30.0, s4 =
999.0/;
Table area(h, parea)
                f     m     m0     kf       hg     sg     hT   hd    s0   s1
s2   s3
*--------------(ga)--------------(m/day)---(m)---(g/l)--(m)---m---------------
---------*
     LeveL1    1630  0.49  0.02   0.036    1.0    9.0   100  2.0   0.40 0.49
0.09 0.02
     LeveL2   20210  0.49  0.02   0.036    1.5   10.0   100  2.2   0.40 0.49
0.09 0.02
     LeveL3  102600  0.49  0.02   0.030    2.0   10.0   100  2.6   0.40 0.49
0.09 0.02
     LeveL4  114290  0.49  0.02   0.026    3.0   11.0   100  3.4   0.40 0.49
0.09 0.02
     LeveL5   61950  0.49  0.02   0.020    5.0   11.0   100  999   0.40 0.49
0.09 0.02
     LeveL6   50970  0.49  0.02   0.016   25.0   11.0   100  999   0.40 0.49
0.09 0.02 ;
*sets

*-----------------------------------------------------------------------*
*---------------------CROPS_parameters---------------------------------*
*-----------------------------------------------------------------------*
sets r   / cotton, wheat, lucerne, gardens, others, void/,
     pr  / area, vol, price, water_N /  ;
set waterCrop /w0, w1, w2, w3, w4, w5, w6/;
```

```
set tveg(r,t)
    / cotton   . (may, jun, jul)
      wheat    . (may, jun)
      lucerne  . (may, jun, jul, aug, sep)
      gardens  . (may, jun, jul, aug, sep)
      others   . (may, jun, jul, aug, sep) /;

parameter w_scale(waterCrop) /w0= 0.0, w1 = 0.5, w2 = 0.6, w3 = 0.7, w4 = 0.8,
w5 = 0.9, w6 = 1.0/;
table w_stress(r, waterCrop)
                  w0     w1      w2      w3      w4      w5      w6
     cotton      1.0    0.700   0.493   0.328   0.162   0.039   0.0
     wheat       1.0    0.980   0.630   0.379   0.190   0.044   0.0
     lucerne     1.0    0.980   0.641   0.467   0.221   0.081   0.0
     gardens     1.0    0.880   0.566   0.343   0.175   0.042   0.0
     others      1.0    0.880   0.566   0.343   0.175   0.042   0.0
     void        1.0    1.000   1.000   1.000   1.000   1.000   0.0   ;

table s_stress(r, sarea)
                  s0    s1    s2    s3     s4
     cotton      1.0   0.7   0.3   0.0    0.0
     wheat       1.0   0.6   0.3   0.0    0.0
     lucerne     1.0   0.8   0.4   0.0    0.0
     gardens     1.0   0.8   0.2   0.0    0.0
     others      1.0   0.7   0.3   0.0    0.0
     void        1.0   1.0   1.0   1.0    0.0 ;

table crop(r,pr)
                area         vol     price     water_N
*---------------(ga)--------(tn/ga)---($)-------(m3/ga)-----*
      cotton   128610        4.4      450       5270
      wheat     53020        5.7       90       2780
      lucerne   33790       25.6       10       8440
      gardens   27880       10.1      200       5950
      others    74000       38.9       50       3000
      void      33000        0.0        0          0 ;

Table w_ET(r,t)         #  flow from w_water to air area(mm/month),
cropsE(s=0)
                oct    nov    dec   jan    feb    mar   apr    may    jun
jul    aug   sep
     cotton     0.0    0.0    0.0   0.0    0.0    0.0  21.5   70.9  161.9
180.0  141.9  62.6
     wheat     24.2   10.8    6.1   6.4   10.5   28.4  80.2  152.0  111.5
0.0    0.0   0.0
     lucerne   24.6    0.0    0.0   0.0    0.0   28.2  53.6  110.8  186.1
208.4  173.0 110.8
     gardens    0.0    0.0    0.0   0.0    0.0   14.3  54.4   98.7  127.5
132.6  115.5  56.6
     others     0.0    0.0    0.0   0.0    0.0   14.3  54.4   98.7  127.5
132.6  115.5  56.6
     void      15.0    8.8    5.0   5.0    7.0   24.3  42.9   70.6   94.8
107.1   95.1  60.8

Table w_norma(r,t)  #   Water vol normal from crops(m3/ga)
              oct    nov    dec   jan    feb    mar   apr     may     jun
jul     aug     sep
```

```
     cotton   0.0    0.0    0.0   0.0    0.0    0.0   0.0  1300.0  2000.0
1970.0     0.0     0.0
     wheat    0.0    0.0    0.0   0.0    0.0    0.0   0.0  1470.0  1310.0
0.0     0.0     0.0
     lucerne  0.0    0.0    0.0   0.0    0.0    0.0   0.0  1500.0  1700.0
1740.0  1800.0  1700.0
     gardens  0.0    0.0    0.0   0.0    0.0    0.0   0.0  1100.0  1200.0
1250.0  1200.0  1200.0
     others   0.0    0.0    0.0   0.0    0.0    0.0   0.0  1100.0  1200.0
1250.0  1200.0  1200.0
     void     0.0    0.0    0.0   0.0    0.0    0.0   0.0     0.0     0.0
0.0     0.0     0.0 ;

*------------------------------------------------------------------------*
*---------------------AREA parameters----------------------------------*
*------------------------------------------------------------------------*
scalar land_areaB, land_areaN, land_areaC, qd_sv;
scalar  h_krit, mln, mlm_m, ga, x, y, yx, x1, x2, y1, y2;
     ga = 10000;
     mln = 1000000;
     mlm_m = 0.001;
     h_krit = 3.0;
     land_areaB = sum (inp, Ir_sys(inp, 'areaB'));
     land_areaN = sum (inp, Ir_sys(inp, 'areaN'));
     land_areaC = sum (r, crop(r,'area'));
*------------------m3/day-from-ga------------------*
     qd_sv =86.4 * sum (out, (Dr_sys(out, 'qd') * Dr_sys(out, 'areaDN')))/
                      sum (out, Dr_sys(out, 'areaDN'));

*  flow from air_area to land (mm/month),(s=0)
parameter u_area(t) /oct 1.02 , nov 15.99, dec 12.40, jan 10.32, feb 4.68, mar
11.38,
                     apr 15.00, may 24.80, jun 9.99, jul 2.08, aug 1.02, sep
1.50/;


table  q_inp(inp,t)  #  mln.m3/month
                oct    nov     dec   jan    feb    mar   apr    may    jun
jul   aug   sep
    inp_name1  14.7   15.3   16.7   16.2  17.2   17.8   19.2   18.3   18.0
15.0  14.5  12.4
    inp_name2  70.2   70.6   78.0   85.0  91.9   99.9  102.7  171.7  220.2
213.7 198.6  63.2
    inp_name3  32.4   33.2   32.3   37.1  42.8   51.9   61.4   71.2   76.1
72.5  52.6  42.5
    inp_L     129.6   85.5  104.4  156.9 109.5   92.1   74.3  172.7  333.9
483.5 402.3 230.2 ;

table  s_inp(inp,t)
                oct    nov     dec   jan    feb    mar   apr    may    jun
jul   aug   sep
    inp_name1   0.7    0.73   0.75   0.74  0.68   0.55   0.47   0.43   0.42
0.4   0.43  0.54
    inp_name2   0.35   0.36   0.37   0.37  0.34   0.28   0.24   0.22   0.21
0.2   0.21  0.27
    inp_name3   0.0    0.0    0.0    0.0   0.0    0.0    0.0    0.0    0.0
0.0   0.0   0.0
```

```
    inp_L       0.35   0.36   0.37   0.37  0.34   0.28   0.24   0.22   0.21
0.2   0.21  0.27 ;

*-----------------------------------water resurs------------------------------
---------------*

Parameters q_FILT(q,t), u_FILT(t), s_FILT(t),
           q_RN(r,t), q_demand(t), q_lc(q,t), q_tr(q,t),
           q_r(q,t),      #  flow in land area from h_water
           q_put(t),
           dq_area(t),
           f_crops(r),
           y_crop(r),
           dy_crop(r);

     f_crops(r)=crop(r, 'area')/ land_areaC;

     q_FILT('w',t)= sum (inp,(1.0 - Ir_sys(inp,'n'))*q_inp(inp,t)*mln);
     q_FILT('s',t)= (sum (inp,(1.0 -
Ir_sys(inp,'n'))*q_inp(inp,t)*mln*s_inp(inp,t)))/q_FILT('w',t);

     u_FILT(t)= q_FILT('w',t)/(land_areaB*ga*tday(t));
     s_FILT(t)= q_FILT('s',t);

     q_tr('w',t)= sum (inp_tr, Ir_sys(inp_tr,'n')*q_inp(inp_tr,t)*mln);
     q_tr('s',t)= (sum (inp_tr,
Ir_sys(inp_tr,'n')*q_inp(inp_tr,t)*s_inp(inp_tr,t)))/q_tr('w',t);

     q_lc('w',t) = Ir_sys('inp_L','n')*q_inp('inp_L',t)*mln;
     q_lc('s',t) = s_inp('inp_L',t);

     q_RN(r,t) = w_norma(r,t)*crop(r,'area');

     q_demand(t) = (sum (r, q_RN(r,t)));
     dq_area(t) = q_demand(t) - q_lc('w',t) - q_tr('w',t);

     q_r('w',t)=q_lc('w',t) + q_tr('w',t) ;
     q_r('s',t)=(q_lc('w',t)*q_lc('s',t) + q_tr('w',t)*q_tr('s',t))/
q_r('w',t) ;

Parameters q_false(t), f_level(h), f_dr(out),  k_def(t), stress_W(r,t),
uE(r,t), u_r(r,t);
     x = sum(h, area(h, 'f'));
     f_level(h)= area(h, 'f')/x;
     x = sum(out, Dr_sys(out, 'areaDN'));
     f_dr(out)= Dr_sys(out, 'areaDN')/x;

*------------------calculate-stress_W-----------------------------*
     loop(t,
        if ( dq_area(t) > 0.0 ,
               k_def(t)= dq_area(t)/q_demand(t);
               q_false(t) = 0;
               x = k_def(t);
               loop(r,
                  y2 = w_stress(r, 'w0');
                  x2 = w_scale('w0');
                  loop(waterCrop$(x>w_scale(waterCrop)),
```

```
                  y1=y2;
                  x1=x2;
                  y2= w_stress(r, waterCrop+1);
                  x2= w_scale(waterCrop+1)
                );
                yx = (y2-y1)/(x2-x1);
                y=y2-yx*(x2-x);
                stress_W(r,t)= 1 - y;
             );
        else
             k_def(t) = 0;
             q_false(t) = -dq_area(t);
             stress_W(r,t)= 0;
        );

     );

     y_crop(r)=crop(r, 'vol')*(1- sum(t, stress_W(r,t)));

*--stream to the land_area (mm/day)------------------------------------------
---*
scalar xx, yy, dx, dy, uu, vv, NB;
*-------------m/day-------------*
    u_r(r,t)=mlm_m*(u_area(t) + 0.1 *(1- stress_W(r,t))*w_norma(r,t))/tday(t);
   loop(t,
     loop(r,
        if(w_ET(r,t)>0.0,
          uE(r,t)=mlm_m*w_ET(r,t)/tday(t);
        else
          uE(r,t)=mlm_m*w_ET('void',t)/tday(t);
        );
      );
    );

Parameters
     x_stressW(r)
     v_crops(t)
     q_h(q,t)
     q_war_wgr(q,t)  #  water flow between land area and ground water, ('+' =
down; '-' = up)
     w_wET(t)
     h_land(t)  ;     #  layer water above (under) surface land ('+' = above;
'-' = under)

set t0(t) /oct/;
set ha(h);
loop(h,
     if(area(h,'hg')<h_krit,
        ha(h) = yes;
     else
        ha(h) = no;
     );
);
Variables
 s_land(h,r,t),      # salinity land in interval (0 - 1m)
 w_land(h,r,t),      #  humidity of land area in interval 0 - 1m.
 h_grWater(h,t),     # delta depth ground water
```

```
 u_g(h,r,t),
 u_gE(h,r,t),
 k_fl(h,r,t),
 u0(t),
 u_dren(h,t),
 u_level(h,t),
 x_damage,       #  damage in PlanningZone
 stress_S(h,r);

Positive variables s_land, w_land;
 w_land.up(h, r, t)= 0.9999 * area(h, 'm');
 w_land.lo(h, r, t)= 1.0001 * area(h, 'm0');
 u_g.lo(h, r, t)=0.0;
 u0.fx(t)=0;
 u_level.fx(h,t)=0;

*----------------------------Calculation---------------------------------------
-----------*
 loop(h,
    h_grWater.l(h, 'oct')=area(h, 'hg');
    x= sum(sarea, s_scale(sarea)*area(h, sarea));
    loop(r,
       s_land.l(h, r, 'oct')= x;
       w_land.l(h, r, 'oct')= 0.8 * area(h, 'm');
    );
 );

Equations

     damage,
     wb_area(h,r,t),          #  humidity of land area
     u_ground(h,r,t),
     u_groundWH(h,r,t),
     u_groundWL(h,r,t),
     sb_area(h,r,t),          #  solinity of land area
     sb0(h,r,t),
     hb_GroundW(h,t),         #  depth ground water
     hb0(h,t),
     koaf_f(h,r,t),
     wb0(h,r,t),
     ub_dren(h,t);

wb0(h,r,t)$(t0(t)) ..
   w_land(h,r,t) =e=  0.4 * area(h, 'm')- tday(t)*(u_g(h,r,t)-u_gE(h,r,t)
                       - u_r(r,t) +(w_land(h,r,t)-
area(h,'m0'))*uE(r,t)/area(h, 'm'));

wb_area(h,r,t)$(not t0(t)) ..
  w_land(h,r,t) =e= (w_land(h,r,t-1))  - tday(t)*(u_g(h,r,t)- u_gE(h,r,t)
                     - u_r(r,t) + (w_land(h,r,t)-area(h,'m0'))*uE(r,t)/area(h,
'm'));

koaf_f(h,r,t) ..
    k_fl(h,r,t) =e= area(h,'kf')*((w_land(h,r,t)-area(h,'m0'))/(area(h, 'm')-
area(h, 'm0')))**3.5;

u_ground(h,r,t) ..
```

```
         u_g(h,r,t) =e=  k_fl(h,r,t)*((w_land(h,r,t)-
area(h,'m0'))/area(h,'m'))**8;

u_groundWH(h,r,t)$(not ha(h)) ..
         u_gE(h,r,t) =e= 0.0;

u_groundWL(h,r,t)$(ha(h)) ..
   u_gE(h,r,t) =e=  uE(r,t)*(1.0 -(0.5*( area(h, 'hg')-1))/h_krit);


sb0(h,r,t)$(t0(t)) ..
    s_land(h,r,t) =e= sum(sarea, s_scale(sarea)*area(h, sarea))
                         - tday(t)*(s_land(h,r,t)*u_g(h,r,t) -
q_r('s',t)*u_r(r,t));

sb_area(h,r,t)$(not t0(t))..
  s_land(h,r,t) =e= s_land(h,r,t-1) - tday(t)*(s_land(h,r,t)*u_g(h,r,t) -
q_r('s',t)*u_r(r,t));

hb0(h,t)$(t0(t))..
  h_grWater(h, t) =e= (tday(t)/area(h,'m'))* (u_FILT(t) + sum(r,
f_crops(r)*u_g(h,r,t))
                        + u0(t) - u_dren(h,t) + u_level(h,t));

hb_GroundW(h,t)$(not t0(t))..
  h_grWater(h, t) =e= h_grWater(h, t-1) + (tday(t)/area(h,'m'))* (u_FILT(t) +
sum(r, f_crops(r)*u_g(h,r,t))
                        + u0(t) - u_dren(h,t) + u_level(h,t));

ub_dren(h,t)$(ha(h))..
  u_dren(h,t) =e= (qd_sv/ga)*(1.0 + h_grWater(h, t)/(area(h, 'hd')-
area(h,'hg')));

  loop(h,
     loop(r,
         x= sum(t$tveg(r,t), (tday(t)*s_land.l(h, r, t)));
         xx= sum(t$tveg(r,t), tday(t));
         x=(x/xx)$(xx>0.0);
         if ( x>0.0,
             x2=s_scale('s0');
             y2=s_stress(r, 's0');
             loop(sarea$(x>s_scale(sarea)),
                y1=y2;
                x1=x2;
                x2= s_scale(sarea+1);
                y2=s_stress(r, sarea+1);
             );
             yx = (y2-y1)/(x2-x1);
             y=y2-yx*(x2-x);
             stress_S.l(h,r)= f_level(h)*(1 - y);
         else
             stress_S.l(h,r)= 0.0;
         );
     );
  );

damage..
```

```
  x_damage  =e=  sum(r, crop(r,'price')*(crop(r,'area') * sum (h,
f_level(h)*(1.0 - stress_S.l(h,r))* y_crop(r))));

Model WS_balans /all/;
solve WS_balans using nlp minimizing x_damage;

w_wET(t)=10000*tday(t)* sum(r, crop(r, 'area')* sum(h,
f_level(h)*w_land.l(h,r,t)*uE(r,t)/area(h, 'm')));

$include 'FergCrop.txt'
$include 'FergWater.txt'
$include 'FergSol.txt'

*Put ' Report 2.1  Water balance   ' Put /;

*FILE Rs / fergOUT /
*Put  Rs

scalar col /15/;
file FergCrop;
Put  FergCrop;
col=17;
FergCrop.nw = 9;
FergCrop.nd = 4;
loop (t, Put @col t.tl; col=col+9;) put/;
loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col stress_W(r,t); col=col+9;) put/;
    );
col=15;
FergCrop.nw = 14;
FergCrop.nd = 1;
loop(r,
        put r.tl;
        col=10;
        x=crop(r, 'area')*y_crop(r);
        xx= x*crop(r, 'price');
        y= crop(r, 'vol')*crop(r, 'area');
        yy=y*crop(r, 'price');
        Put @col x;
        col = col+14;
        Put @col xx;
        col = col+14;

        Put @col y;
        col = col+14;

        Put @col yy;
        put/;

    );

FergCrop.nw = 8;
FergCrop.nd = 5;
put 'qd_sv = '; put qd_sv;
x=qd_sv/ga;
```

```
put 'u_dr='; put x;
put/;
   col=13;
   loop (t, Put @col t.tl; col=col+8;) put/;
   col=10;
   loop(h,
        put h.tl;
        col=10;
        loop (t, Put @col u_dren.l(h,t); col=col+8;) put/;
   );
put/;
   col=15;
   put 'u_FILT';
   loop (t, Put @col t.tl; col=col+9;) put/;
   col=10;
        loop (t, Put @col  u_FILT(t); col=col+9;) put/;
```

==

```
file FergWat;
Put  FergWat;
col=13;
FergWat.nw = 8;
loop (t, Put @col t.tl; col=col+8;) put/;
q_put(t)= q_FILT('w',t)/mln;

        put 'q_FILT';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

col=13;
q_put(t)= q_tr('w',t)/mln;
        put 'q_TRANS';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

col=13;
q_put(t)= q_lc('w',t)/mln;
        put 'q_LOCAL';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

col=13;
q_put(t)= q_r('w',t)/mln;
        put 'q_T+q_L';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;
col=13;
q_put(t)= q_demand(t)/mln;
        put 'q_DEMAND';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;
col=13;
q_put(t)= dq_area(t)/mln;
        put 'q_DEF';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;
```

```
col=13;
q_put(t)= w_wET(t)/mln;
        put 'q_wET';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

col=13;
q_put(t)=sum(r, 10 * u_area(t)*crop(r,'area'))/mln;
        put 'q_Precip';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;
col=13;
q_put(t)=0.01*tday(t)* sum(r, crop(r,'area')* sum(h,
f_level(h)*u_g.l(h,r,t)));
        put 'q_ground';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

col=13;
q_put(t)=0.01*tday(t)* sum(r, crop(r,'area')* sum(h,
f_level(h)*u_gE.l(h,r,t)));
        put 'q_gE';
        col=10;
        loop (t, Put @col q_put(t); col=col+8;) put/;

FergWat.nw = 7;
FergWat.nd = 4;

col=15;
loop (t, Put @col t.tl; col=col+9;) put/;
loop(r,
        put r.tl;
        col =10;
        loop (t, Put @col u_r(r,t); col=col+9;) put/;
);

col=15;
loop (t, Put @col t.tl; col=col+9;) put/;
loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col stress_W(r,t); col=col+9;) put/;
    );

put/;
put/;
put/;

loop(h,
   col=25;
   Put @col h.tl;  put/;
   col=15;
   loop (t, Put @col t.tl; col=col+9;) put/;
   col=10;
   loop(r,
        put r.tl;
        col=10;
```

```
        loop (t, Put @col w_land.l(h,r,t); col=col+9;) put/;
   );
);
put/;
col=15;
put 'u_r';
loop (t, Put @col t.tl; col=col+9;) put/;
loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col u_r(r,t); col=col+9;) put/;
    );

put/;
   col=15;
   put 'uE';
   loop (t, Put @col t.tl; col=col+9;) put/;
   col=10;
   loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col  uE(r,t); col=col+9;) put/;
   );

put/;
loop(h,
   col=25;
   put 'u_g';
   Put @col h.tl;  put/;
   col=15;
   loop (t, Put @col t.tl; col=col+9;) put/;
   col=10;
   loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col u_g.l(h,r,t); col=col+9;) put/;
   );
);

put/;
put/;
   col=13;
   loop (t, Put @col t.tl; col=col+8;) put/;
   col=10;
   loop(h,
        put h.tl;
        col=10;
        loop (t, Put @col h_grWater.l(h,t); col=col+8;) put/;
   );

======================================================

file FergSol;
Put  FergSol;
col=17;
FergSol.nw = 9;
FergSol.nd = 4;
```

```
col=10;
loop (h, Put @col area(h,'hg'); col=col+9;) put/;
col=10;
loop(h, put @col f_level(h); col=col+9;) put/;
loop(r,
        put r.tl;
        col =10;
        loop (h, Put @col stress_S.l(h,r); col=col+9;) put/;
);

FergSol.nw = 8;
col=15;
loop (t, Put @col t.tl; col=col+9;) put/;


loop (h,
  col=25;
  Put @col h.tl;  put/;
  col=15;
  loop(r,
        put r.tl;
        col=10;
        loop (t, Put @col s_land.l(h,r,t); col=col+9;) put/;
    );
);
```