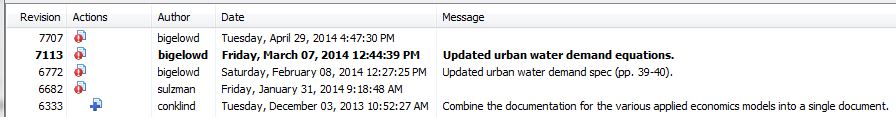
WW2100 Applied Economics Models As-Built

Dave Conklin 12/3/13, 5/15/14, 5/23; James Sulzman 1/31/14; Dan Bigelow 2/8/14, 3/7, 4/29, 7/7

**Change history**

This document is in the Envision Subversion repository at StudyAreas/WW2100/Docs as “WW2100 Applied Economics Models As Built.docx”. As of 5/15/14, the Subversion log is



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Overview

There are seven applied economics models in the WW2100 Envision system:

Population growth

Crop choice

Irrigation decision

Farmland rent

Land use transition

Urban growth area expansion

Urban water demand

The models were specified by faculty members in the Applied Economics department at Oregon State University, led by Prof. Bill Jaeger. They were implemented in Envision by Dave Conklin, a contractor to OSU, and by James Sulzman in the OSU BEE Dept., and tested by Dan Bigelow, a PhD student in the Applied Econ department.

This document summarizes how the models were implemented in Envision and provides references to their specifications.

All seven models are implemented in Envision as part of the WW2100AP.dll autonomous process plugin. The WW2100AP dynamic library is intended to encapsulate annual timestep autonomous processes which are specific to the WW2100 project. Besides the econ models, WW2100AP also has code for a fish model and code for the forest model.

There is a single XML file used by the WW2100AP library, which has separate sections for each model. Appendix A is a listing of the WW2100AP.xml file as of repository version 7909 on 5/14/14. Further information about the XML file is available later in this document.

Written specifications for the seven econ models are included in Appendices B-J. The documents in those appendices are generally as they existed at the time agreement was reached on the spec and work was begun on implementation. In some cases they were revised during the implementation process to reflect the resolution of problems discovered along the way. Little or no effort has been made to edit or tidy up the documents in Appendices B-J; they are the actual working documents used to inform and guide the implementation process.

The WW2100AP.dll provides a single “master” process; the various models are implemented as subprocesses which run at different times. There are 9 different autonomous process blocks in the WW2100.envx file which use WW2100AP.dll; they all have different ID numbers, and the ID number is used to control which subprocess runs. Each model has its own XML block in the WW2100AP.xml file:

<ww2100 ... >

<ColdStart id=...

<fish id=...

<carbon id=...

<land\_use\_transitions id=...

<urban\_water id=...

<DGVMvegtypeData id=...

<irrigation\_choice id=...

<popGrowth id=...

<farmland\_rent id=...

<crop\_choice id=...

<UGA\_expansion id=...

</ww2100>

Input parameters and files used by multiple models

Near the beginning of the XML file there are tags for parameters and input files which are used by more than one of the economics models:

<ww2100 test\_mode="0" tau\_climate="30." tau\_WR="10." land\_use\_interval="5"

UGApop\_file="/Envision/StudyAreas/WW2100/ARECmodels/UGBpop.csv"

household\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/hhold\_income.csv" >

<time\_dependent\_coefficient symbol="Eyr" method="timeseries\_linear" value="(2010,1), (2100,1)"

description="energy cost index time series" />

<climate\_files

precip\_filename = "/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/ppt.nc"

tmin\_filename ="/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/tmin.nc" />

The tau\_climate and tau\_WR parameters specify the tau parameter in the time-smoothing function used for long term mean climate parameters (tau\_climate) and the water right shutoff parameter (tau\_WR). During the simulation, the long term mean is updated each year using

mean\_val = prev\_mean\_val\*exp(-1/tau) + new\_raw\_val\*(1 - exp(-1/tau))

The climate files, which are in netCDF format, provide monthly temperature and precipitation values for cells in a ~4km grid covering the study area. Data is used for the 30 years (i.e. tau\_climate) prior to the first simulation year, and for each simulation year. The temperature data represents monthly means of the diurnal minimum temperatures, in deg C. Precipitation is in mm H2O. Starting values for the long term means are calculated at the beginning of each simulation. A line in the WW2100AP.h source file records the first calendar year of the climate data; as of repository version 7900 on 5/14/14, the line is

#define FIRST\_YEAR\_OF\_CLIMATE\_DATA 1895

The associated climate data files are the combination of PRISM data for 1895-2009 and future climate scenario data for 2010-2099 (HadGEM) or 2010-2100 (MIROC and GFDL), as output by MC2. MC2 uses the value NC\_FILL\_FLOAT from the netcdf.h source file as a no-data token in gridcells outside the study area, so the Econ Model code must test for that value (a number > 1e38).

The string “CLIMATE\_SCENARIO\_NAME” in the paths for the climate data files is replaced at runtime with one of “MIROC”, “HadGEM”, or “GFDL” as appropriate.

The land\_use\_interval tag specifies the number of years between recalculation of land-use transition probabilities and between urban growth area expansion calculations

The UGApop\_file has population projections for urban growth areas (UGAs). These projections are used in the population growth model and in the urban water demand model.

The household\_income\_file is used in the land-use transition model and the urban water demand model.

The Eyr energy cost index time series is used in the irrigation decision and farmland rent models.

Test modes

The test\_mode tag is used repeatedly in the XML file to specify whether or not the WW2100AP process as a whole is in test mode, and to specify which submodel is in test mode. The effect of placing the entire WW2100AP process in test mode (i.e. <ww2100 test\_mode=’1‘ ...) is to cause each submodel to write a line to the Envision log file every time it is invoked in a time step. The effect of placing a submodel in test mode (e.g. <irrigation\_choice id=’...‘ test\_mode=’1‘ ...) is to cause the submodel to place debugging information in attributes X0, X1, ..., PROB0, PROB1, ..., andBETAX, created for that purpose. There is only a single set of such attributes, so only one submodel should be placed in test mode at a time. Not all submodels have test modes. For those which do, the specific effect of test mode will be described in the model’s section below.

Population growth model

Population projections, at 5 year intervals from 2010 thru 2100, for each of the 69 urban growth areas, and for each of 813 rural population areas (RPAs), are read from text files. The files were supplied by Dan Bigelow. Because the UGA population projections are also used by another model, the file name and path for the UGA population file is specified near the beginning of the WW2100AP.xml file, using the UGApop\_file tag. The file name and path for the RPA file is specified in the short block of the WW2100AP.xml file which begins with the popGrowth tag. The name of the IDU attribute which stores the RPA index is also specified in the popgrowth block, using the ruralPopUnitCol tag.

The population growth model reads data from the POP and POPDENS attributes, and writes new calculated values out to those attributes. Values written to the POP attribute are rounded to whole numbers. In the initial condition of the IDU database, population may be located anywhere, but new population is added only in privately-owned, developed IDUs within UGAs and only in RPAs outside the UGAs. Within a given IDU, population is arranged in the privately-owned, developed IDUs so that they all have the same population density.

The population growth model produces a single output, which is a data object named “UGAadjPopDens(people per acre)” containing the year-by-year “adjusted population densities” for 8 of the largest UGAs. “Adjusted population density” is defined as the total population of the UGA divided by the area of the privately-owned, developed land within the UGA.

Documents used to specify the population growth model during coding are in Appendices B and C.

Irrigation decision model

The domain of the irrigation decision model is the IDUs for which LULC\_A is 2 {Agriculture} and which are irrigable. Irrigibility is determined by reading and decoding the WREXISTS attribute. To be considered irrigable, the WREXISTS attribute must have the irrigation bit set in the use field and either the surface bit or the groundwater bit or both set in the permit field. The output of the irrigation decision model is placed in the IRRIGATION attribute: 1 means a decision has been made to irrigate in the current year, while 0 means a decision has been made not to irrigate.

The block for the irrigation decision model in the XML file allows the user to specify coefficients beta0 thru beta16. These are used with 16 independent variables in a linear function to calculate betaX. betaX in turn is used in an exponential function to calculate a probability of irrigating. Finally, a random draw from the unit interval is compared with the calculated irrigation probability to decide whether or not to irrigate for the IDU.

The irrigation decision model has a test mode and makes use of attributes X0 thru X16, BETAX, and PROB0. The independent variables are stored in X1 thru X16, betaX is stored in BETAX, and the probability of irrigating is stored in PROB0.

Further details of the irrigation decision model may be found in Appendix E.

Crop choice model

The domain of the crop choice model is the IDUs for which LULC\_A is 2 {Agriculture}. IDUs which are in orchards or vineyards are never changed to a different crop. Otherwise, after the first year of the simulation, for any IDU in the domain for which the long term farmland rent estimate (attribute FRMRNT\_LR) is less than $1, the crop choice is immediately set to fallow. The test of FRMRNT\_LR less than $1 is omitted in the first year because at the time the crop choice model runs in the first year, the long term farmland rent has not yet been calculated.

For all other IDUs in the domain, probabilities are calculated for each of seven named crops, in a way roughly analogous to the calculation of the probability of irrigation in the irrigation decision model. For the crop choice model there are 15 coefficients (beta0 thru beta14) for each crop; the coefficients are read from a file specified by the coefficients\_file tag in the crop choice block of the XML file. The same 14 independent variables are used for all the possible crops. Three of the independent variables are derived from time series specified by the time\_dependent\_data tags for the symbols PG (price of grass seed), PW (price of wheat), and “snowpack”. The snowpack time series specifies the April 1st regional snowpack for each year starting 10 years prior to the first year of the simulation, and going thru the final year of the simulation.

In addition to the 7 named crops, an eighth possible choice is “Other crops”. The probability of choosing “Other crops” is derived from the other 7 probabilities, making use of the fact that the 8 probabilities must sum to 1. The output of the crop choice model is the LULC\_C code for the chosen crop, which is placed in the VEGCLASS attribute. Envision automatically propagates the LULC\_C change (LULC\_C is called “VEGCLASS” in the WW2100 system) up to LULC\_B and LULC\_A, using the LULC hierarchy.

Two of the crop-choice independent variables, tmin and precip, are time series, specified using time\_dependent\_data tags in the XML. The IDU-specific tmin and precip values are demeaned prior to entering the crop-choice probability formulae. Originally basin-wide mean values for tmin and precip were also taken from the XML, but as of version 7899 on 5/14/14, basin-wide temporally smoothed mean values for tmin and precip, calculated in each annual timestep, are used for demeaning the independent tmin and precip variables. Moreover, the gridcell tmin and precip values used as the independent tmin and precip variables are also temporally smoothed.

Crop choice does have a test mode. The independent variables are placed X0 thru X14. For the chosen crop, the linear function of the coefficients and the independent variables is placed in BETAX. The probabilities for the 8 crop choices are placed in PROB0 thru PROB7.

More information on the crop choice model is located in Appendix D.

Farmland rent model

The domain of the farmland rent model is the IDUs for which LULC\_A is 2 {Agriculture} or 4 {Forest}. The model estimates a rent for the current year and places it in the FRMRNT\_YR attribute, and also a long-term rent, which it places in the FRMRNT\_LR attribute. The difference between FRMRNT\_YR and FRMRNT\_LR is that the current year value reflects only irrigation success in the current year, while the long term value reflects irrigation rent over the last 10 years (tau\_WR). For ag IDUs but not for forest IDUs, the model populates one additional attribute, IRRH2OCOST, the cost of irrigation water for the IDU.

Both forms of the rent are estimated as linear functions of 15 coefficients (a0-a14) and 14 independent variables. The coefficients are specifiable in the XML file, including 4 additional coefficients used in constructing the independent variables. Two of the independent variables are time series, specified using time\_dependent\_data tags in the XML. Independent variables for elevation, precipitation, and monthly mean values of diurnal minimum temperatures are used in demeaned form. The original bsin-wide mean value for elevation used for demeaning the independent variable elevation is specifiable in the XML (a15). Originally basin-wide mean values for tmin and precip were also taken from the XML (a16 and a17), but as of version 7899 on 5/14/14, basin-wide temporally smoothed mean values for tmin and precip, calculated in each annual timestep, are used for demeaning the independent tmin and precip variables. Moreover, the gridcell tmin and precip values used as the independent tmin and precip variables are also temporally smoothed. The a16 and a17 values in the XML for Farmland Rent are ignored.

The farmland rent model does have a test mode. The independent variable values are placed in X1-X14.

Additional details of the farmland rent model are in Appendix F.

Urban water demand model

The urban water demand model populates the H2ORESIDNT and H2OINDCOMM attributes for all the IDUs. The values for those attributes are in units of ccf/day. Values are calculated differently for IDUs within UGAs compared to rural IDUs. For rural IDUs, H2OINDCOMM is always zero, and H2ORESIDNT is only non-zero in populated IDUs. H2OINDCOMM is also zero within all the UGAs except the “big 4”: Metro, Salem-Keiser, Corvallis, and Eugene-Springfield.

The model tries to place the demand within an urban growth area only on IDUs which are served by a municipal water district. If there are no municipal water districts coincident with the UGA, then the demand is spread evenly across all the IDUs in the UGA.

The XML for the urban water model requires the user to identify input data files for manufacturing income, commercial income, and cooling costs, and to specify price information for the big 4 UGAs.

The urban water model has a test mode. When in test mode, it stores into X0-X5:

X0 = the “permit” field from WREXISTS

X1 = the “use” field from WREXISTS

X2 = 1 if the municipal use bit is set in the WREXISTS permit field, otherwise 0

X3 = for IDUs with UGB>0, the ratio of the combined area of the water districts

in the UGB to the total area of the UGB; otherwise 0

X4 = 1 if the IDU is irrigable; otherwise 0

X5 = 1 if the IDU is irrigable from groundwater; otherwise 0

More information about the urban water model is in Appendix H.

Land-use transition model

The land-use transition model moves IDUs between forest and agricultural uses, and from both of those uses into developed use. To move an IDU into agricultural use, it writes the code for “Fallow/Idle Cropland” into the VEGCLASS attribute. To move an IDU into forest use, it writes the code for “DF:GFp” (Douglas-fir cover type, grass-forb post-disturbance structural stage) into VEGCLASS, the code for “FWI” (forest - western hemlock intermediate) into the PVT attribute, and zero into the AGECLASS attribute. To move an IDU into developed use, it writes the code for “Developed Undifferentiated” into VEGCLASS. The Envision system automatically propagates the changes to VEGCLASS up to the LULC\_B and LULC\_A attributes, using the LULC hierarchy.

The model also stores into the PROBUSECHG (probability of land-use change) and PROB\_DEV (probability of being developed) attributes. For an IDU which actually changes land-use in a given year, the negative of the probability of land-use change is stored into PROBUSECHG for that one year, so that a query on “PROBUSECHG<0” can be used to identify all the IDUs which changed uses in the most recent simulation year. Likewise the PROB\_DEV attribute can be used to identify which IDUs were converted to a developed use in the most recent year. Specifically, PROB\_DEV takes on the negative of the probability of development if an IDU is converted from agriculture to development, and -1 plus the negative of the probability of development if the IDU is converted from forest to development.

The land-use transition model is complicated, with many coefficients. An effort has been made to allow the user to specify the values of all the coefficients in the XML block for the model. A comparison of the coefficient and parameter description tags in the XML block, with the specification for the model in Appendix I, will help the user to determine where each number in the spec is recorded in the XML.

The land-use transition model produces 11 output variables:

- developed fractions for the 8 largest UGAs

- the number of agricultural IDUs eligible to change use

- the number of forest IDUs eligible to change use

- a data object named “LandUseTransitionsPerEligibleIDU” with columns for Ag->Developed, Ag->Forest,

Forest->Developed, and Forest->Ag

The “developed fraction” for an urban growth area is the amount of the privately-owned developed land in the UGA expressed as a fraction of all the developable land in the UGA, where developable land is any privately-owned land with LULC\_A = 1 {Developed} or 2 {Agriculture} or 4 {Forest}.

The land-use transition model has a test\_mode tag which can take on the values 0, 1, 2, or 3. Zero means test mode is off. Any value greater than zero causes the predicted land values ($/acre) for developed use, agricultural use, and forest use to be stored into PROB0, PROB1, and PROB2. The independent variables used in the estimation of land values are stored into X0-X11; when test\_mode is 1, the independent variables for the developed use estimate are stored in X0-X11; when test\_mode is 2, the independent variables for the ag use estimate are stored; and when test\_mode is 3, the independent variables for the forest use estimate are stored.

Additional information on the land-use transition model is available in Appendices G, I, and J.

Urban growth area expansion model

The UGA expansion model operates on the UGAs which are identified by the UGA tag in the model’s XML block. The tag provides the coordinates of the city center and a threshold for the UGA’s developed fraction. At five-year intervals (land\_use\_interval), the model tests the UGA’s developed fraction against the specified threshold. When the threshold is exceeded, the model attempts to add adjacent rural IDUs to the UGA until the developed fraction is once again below the threshold. The rules for determining which IDUs to add and in what order are described in Appendix I. The model adds an IDU to an urban growth area by setting the UGB attribute to the code for the UGA.

The UGA expansion model produces one output variable, a data object named “UGAdevelopedFractions”. The object contains the year-by-year developed fractions for each of the target UGAs.

The UGA expansion model has a test mode. In test mode, the model writes a line to the Envision log file describing each IDU added to an urban growth area, and an additional line to the log file when it adds a row to the UGAdevelopedFractions data object.

Appendix A. WW2100AP.xml

Subversion repository file StudyAreas/WW2100/WW2100AP.xml revision 7909, 5/14/14. The text has been reformatted slightly for readability; sections for the fish and forest models have been elided.

<?xml version="1.0" encoding="utf-8"?>

<envision>

<ww2100 test\_mode="0" tau\_climate="30." tau\_WR="10." land\_use\_interval="5"

UGApop\_file="/Envision/StudyAreas/WW2100/ARECmodels/UGBpop.csv"

household\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/hhold\_income.csv" >

<time\_dependent\_coefficient symbol="Eyr" method="timeseries\_linear" value="(2010,1), (2100,1)"

description="energy cost index time series" />

<climate\_files

precip\_filename = "/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/ppt.nc"

tmin\_filename ="/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/tmin.nc" />

<ColdStart id ="5" />

<!--

<ColdStart id ="5" use\_vegclass\_initialization ="0"

PopulationUnitsFile="/Envision/StudyAreas/WW2100/ARECmodels/IDU\_UGB\_RR\_110413.csv" />

<ColdStart id ="5" use\_vegclass\_initialization ="0" >

initial\_irrigation\_fraction="0.6"

SWHCfile="/Envision/StudyAreas/WW2100/MC2data/WW2100\_Hist\_single.nc"

PopulationUnitsFile="/Envision/StudyAreas/WW2100/ARECmodels/IDU\_UGB\_RR\_110413.csv" >

<ForestSTMfiles

DGVMvegtype\_file = "/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/vtype.nc"

CoverTypes\_file = "/Envision/StudyAreas/WW2100/ForestSTM/CoverTypes.csv"

StructuralStages\_file = "/Envision/StudyAreas/WW2100/ForestSTM/StructuralStages.csv"

TransitionTypes\_file = "/Envision/StudyAreas/WW2100/ForestSTM/Transition Types.csv"

Stratum2PVT\_file ="/Envision/StudyAreas/WW2100/ForestSTM/Stratum2PVT.csv"

LAIandC\_file ="/Envision/StudyAreas/WW2100/ForestSTM/LAIandC.csv"

DeterministicTransitionInput\_file = "/Envision/StudyAreas/WW2100/ForestSTM/

Deterministic Transitions.csv"

ProbabilisticTransitionInput\_file =" /Envision/StudyAreas/WW2100/ForestSTM/

Probabilistic Transitions.csv"

DeterministicTransitionOutput\_file = "/Envision/StudyAreas/WW2100/ForestSTM/

wv\_deterministic\_transition\_lookup.csv"

ProbabilisticTransitionOutput\_file = "/Envision/StudyAreas/WW2100/ForestSTM/

wv\_probability\_transition\_lookup.csv"

/>

</ColdStart>

-->

<fish id="95"> … </fish>

<carbon id='-1' > </carbon>

<!-- The land use transition model always signals which IDUs have transitioned by negating the value in the PROBUSECHG column.

Test mode in the Land Use Transitions model works this way:

test\_mode can be set to 0, 1, 2, or 3. 0 turns off test mode.

Whenever test\_mode is >0, then

- the PROB0, PROB1, and PROB2 columns are used to store the predicted values for developed use, agricultural use, and forest use, respectively, and

- the X0 thru X13 columns are used to store the independent variable values for the predicted value of developed use (test\_mode=1), agricultural use (test\_mode=2), or forest use (test\_mode=3)

- the BETAX column is used to store the beta\*X sum corresponding to the independent variable values in the X0 thru X13 columns

-->

<land\_use\_transitions id='49' test\_mode ='0' >

<!--should be id='49'-->

<developed\_use>

<coefficients>

<coefficient symbol='beta0' value='8.367687725' description='constant' />

<coefficient symbol='beta1' value='0.4253438' description='UGB' />

<coefficient symbol='beta2' value='0.0985166' description='pop\_den' />

<coefficient symbol='beta3' value='0.7030271' description='ln\_HH\_inc' />

<coefficient symbol='beta4' value='0.001059' description='imp' />

<coefficient symbol='beta5' value='-0.0398208' description='citydist' />

<coefficient symbol='beta6' value='0.0006302' description='citydist\_sq' />

<coefficient symbol='beta7' value='0.0900482' description='Benton\_group' />

<coefficient symbol='beta8' value='-0.2580525' description='Lane\_group' />

<coefficient symbol='beta9' value='0.2457331' description='Washington\_group' />

</coefficients>

<coefficient symbol='Correction\_factor' value='1.034978' />

<parameter symbol='imp' value='93.92385' description=

'year 2000 developed-use ave improvement value' />

</developed\_use>

<agricultural\_use >

<coefficients>

<!--from Dan Bigelow's WW2100AP\_083013.xml file-->

<coefficient symbol='beta0' value='7.2543813' description='constant' />

<coefficient symbol='beta1' value='-0.0078781' description='acres' />

<coefficient symbol='beta2' value='-0.0157249' description='slope' />

<coefficient symbol='beta3' value='-0.0243433' description='citydist' />

<coefficient symbol='beta4' value='0.0006525' description='citydist\_sq' />

<coefficient symbol='beta5' value='-0.1964286' description='Benton\_group' />

<coefficient symbol='beta6' value='-0.333473' description='Lane\_group' />

<coefficient symbol='beta7' value='-0.8587856' description='Washington\_group' />

<coefficient symbol='beta8' value='0.0009659' description='imp' />

<coefficient symbol='beta9' value='0.0025979' description='farm\_rent' />

<coefficient symbol='beta10' value='0.0020389' description='mean\_imp' />

</coefficients>

<coefficient symbol='Correction\_factor' value='1.166662' />

<parameter symbol='imp' value='57.92065' description=

'year 2000 agricultural-use ave improvement value' />

<parameter symbol='mean\_imp' value='38.712768' description=

'mean agricultural-use improvement value' />

</agricultural\_use>

<forest\_use>

<coefficients>

<!--from Dan Bigelow's WW2100AP\_083013.xml file-->

<coefficient symbol='beta0' value='5.9291783' description='constant' />

<coefficient symbol='beta1' value='-0.0003559' description='acres' />

<coefficient symbol='beta2' value='-0.0502137' description='slope' />

<coefficient symbol='beta3' value='-0.0011574' description='elev' />

<coefficient symbol='beta4' value='-0.000089' description='riv\_feet' />

<coefficient symbol='beta5' value='0.2073242' description='PNI' />

<coefficient symbol='beta6' value='0.0391123' description='ugbdist' />

<coefficient symbol='beta7' value='-0.1114657' description='citydist' />

<coefficient symbol='beta8' value='0.0018771' description='citydist\_sq' />

<coefficient symbol="beta9" value="-0.9971978" description="Benton\_group" />

<coefficient symbol="beta10" value="-0.3252957" description="Lane\_group" />

<coefficient symbol='beta11' value='-1.245103' description='Washington\_group' />

<coefficient symbol='beta12' value='0.0003241' description='imp' />

<coefficient symbol='beta13' value='0.0059264' description='mean\_imp' />

</coefficients>

<coefficient symbol='Correction\_factor' value='1.225823' />

<parameter symbol='imp' value='47.81576' description=

'year 2000 forest-use ave improvement value' />

<parameter symbol='mean\_imp' value='25.6702726' description=

'mean forest-use improvement value' />

</forest\_use>

<transitions >

<coefficient symbol='self' value='0.00489' description='use w/ ARa and FRf' />

<coefficient symbol='crossR' value='0.00242' offset\_value='-7.799' description=

'use w/ FRa and ARf' />

<coefficient symbol='DR' value='0.00013' offset\_value='-4.788' />

<transition from\_use='ag' >

<to to\_use='ag' >

<parameter symbol='max' value='200' />

<coefficient symbol='scale\_factor' value='0.05' description='coef of ag\_val' />

</to>

<to to\_use='forest' >

<parameter symbol='max' value='2000' />

<coefficient symbol='scale\_factor' value='2.0' description='coef of for\_val'/>

</to>

<to to\_use='developed' >

<parameter symbol='max' value='50000' />

<coefficient symbol='scale\_factor' value='0.03' description='coef of dev\_val'/>

</to>

</transition>

<transition from\_use='forest' >

<to to\_use='ag' >

<parameter symbol='max' value='2000' />

<coefficient symbol='scale\_factor' value='0.5' description='coef of ag\_val' />

</to>

<to to\_use='forest' >

<parameter symbol='max' value='200' />

<coefficient symbol='scale\_factor' value='0.7' description='coef of for\_val'/>

</to>

<to to\_use='developed' >

<parameter symbol='max' value='50000' />

<coefficient symbol='scale\_factor' value='0.03' description='coef of dev\_val'/>

</to>

</transition>

</transitions>

</land\_use\_transitions>

<!--urban\_water should be id='52'

When urban water test mode is 1, diagnostic values are stored in X0-X3:

X0 = "use" field from WREXISTS

X1 = "permit" field from WREXISTS

X2 = "muni" field from WREXISTS

X3 = for IDUs with UGB>0, the ratio of the combined area of the water districts

in the UGB to the total area of the UGB; otherwise 0

X4 = IsIrrigable(WREXISTS)

X5 = IsIrrigableFromGroundwater(WREXISTS)

-->

<urban\_water id='52' test\_mode="0"

manufacturing\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/mfg\_income.csv"

commercial\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/comm\_income.csv"

cooling\_cost\_file="/Envision/StudyAreas/WW2100/ARECmodels/cooling\_cost.csv" >

<prices>

<price\_ccf area="Portland Metro" residential="2.44" non-residential="2.44" IBR="0"/>

<price\_ccf area="Salem-Keizer" residential="2.04" non-residential="1.50" IBR="0"/>

<price\_ccf area="Corvallis" residential="1.93" non-residential="2.11" IBR="1"/>

<!--

<price\_ccf area="Eugene" residential="1.25" non-residential="1.57" IBR="1"/>

<price\_ccf area="Springfield" residential="1.26" non-residential="1.20" IBR="1"/>

-->

<price\_ccf area="Eugene-Springfield" residential="1.25" non-residential="1.48"

IBR="1"/>

</prices>

</urban\_water>

<DGVMvegtypeData id='80' > … </DGVMvegtypeData>

<irrigation\_choice id="50" test\_mode="0" >

<!-- s/b id=50 -->

<coefficients>

<coefficient symbol="beta0" value="2.24871" description="intercept" />

<coefficient symbol="beta1" value="-0.09432" description="Precip dev, June" />

<coefficient symbol="beta2" value="-0.41341" description="Precip dev, July" />

<coefficient symbol="beta3" value="-0.15841" description="Precip dev, August" />

<coefficient symbol="beta4" value="-0.0098" description="Elevation (meters)" />

<coefficient symbol="beta5" value="0.00083" description=

"Elevation\*spring precip (avg. Apr-Jun" />

<coefficient symbol="beta6" value="0.43069" description="EFU (0/1)" />

<coefficient symbol="beta7" value="0.33113" description="Groundwater right (0/1)" />

<coefficient symbol="beta8" value="-0.00842" description="Poor drainage (%)" />

<coefficient symbol="beta9" value="-0.00949" description=

"Groundwater-right\*depth-to-groundwater (m)" />

<coefficient symbol="beta10" value="-0.21901" description=

"Water holding capacity (cmH2O)" />

<coefficient symbol="beta11" value="-0.02615" description=

"Distance to Willamette R. (km)" />

<coefficient symbol="beta12" value="-0.00873" description=

"Distance to nearest major city (km)" />

<coefficient symbol="beta13" value="0.83972" description="LCC1 (0/1)" />

<coefficient symbol="beta14" value="1.07992" description="LCC2 (0/1)" />

<coefficient symbol="beta15" value="0.82066" description="LCC3 (0/1)" />

<coefficient symbol="beta16" value="1.4981" description="LCC4 (0/1)" />

</coefficients>

</irrigation\_choice>

<!--should be popGrowth id="81"-->

<popGrowth id="81" ruralPopUnitCol="RPA"

RRpop\_file="/Envision/StudyAreas/WW2100/ARECmodels/RRpop.csv"

/>

<!--should be farmland\_rent id="81"-->

<farmland\_rent id="81" test\_mode="0" >

<coefficients>

<coefficient symbol="a0" value="1.206" description="intercept" />

<coefficient symbol="a1" value="104.7" description="LCC1 (0/1)" />

<coefficient symbol="a2" value="95.6" description="LCC2 (0/1)" />

<coefficient symbol="a3" value="69.9" description="LCC3 (0/1)" />

<coefficient symbol="a4" value="66.6" description="LCC3 (0/1)" />

<coefficient symbol="a5" value="20.5" description="LCC5 (0/1)" />

<coefficient symbol="a6" value="20.5" description="LCC6 (0/1)" />

<coefficient symbol="a7" value="19.9" description="LCC7 (0/1)" />

<coefficient symbol="a8" value="38.9" description="IRR\*LCC1" />

<coefficient symbol="a9" value="39.1" description="IRR\*LCC2" />

<coefficient symbol="a10" value="17.8" description="IRR\*LCC3" />

<coefficient symbol="a11" value="22.1" description="IRR\*LCC4" />

<coefficient symbol="a12" value="-0.04" description="ElevDeMean" />

<coefficient symbol="a13" value="1.37" description="PrDeMean" />

<coefficient symbol="a14" value="26.6" description="MinTempDeMean" />

<coefficient symbol="a15" value="93.68" description="mean Elev" />

<coefficient symbol="a16" value="13.49"

description="mean growing season precip, inH2O" />

<coefficient symbol="a17" value="8.581" description="mean growing season tmin" />

<coefficient symbol="a18" value="2.0"

description="placeholder coefficient in pumping cost expression" />

</coefficients>

<time\_dependent\_data symbol="Cw\_groundwater" type="timeseries" method="linear"

value="(2010,0), (2100,0)" description="irrigation H2O cost from groundwater" />

<time\_dependent\_data symbol="Cw\_surfacewater" type="timeseries" method="linear"

value="(2010,0), (2100,0)" description="irrigation H2O cost from surface water" />

</farmland\_rent>

<!-- s/b id="51" -->

<crop\_choice id="51" test\_mode="0"

coefficients\_file="/Envision/StudyAreas/WW2100/ARECmodels/cropchoice.csv" >

<time\_dependent\_datasets>

<time\_dependent\_data symbol="PG" description="price of grass seed, $/ton"

type="timeseries" method="linear" value="(2010, 0.), (2100, 0.)" />

<time\_dependent\_data symbol="PW" description="price of wheat, $/bushel"

type="timeseries" method="linear" value="(2010, 0.), (2100, 0.)" />

<time\_dependent\_data symbol="snowpack" description="regional snowpack on Apr 1"

type="file" method="linear" value= "/Envision/StudyAreas/WW2100/WW2100APdata/

CLIMATE\_SCENARIO\_NAME/snowpack.csv" />

</time\_dependent\_datasets>

</crop\_choice>

<UGA\_expansion id="90" test\_mode="0" default\_threshold\_pct="80">

<UGAs> <!--Cottage Grove city center coords are approximate-->

<!-- <UGA id="" name="" city\_center\_E="" city\_center\_N="" threshold\_pct="80" display="0" /> -->

<UGA id="2" name="Albany" city\_center\_E="493141" city\_center\_N="4942404" threshold\_pct="80" display="1" />

<UGA id="12" name="Corvallis" city\_center\_E="476957" city\_center\_N="4934821" threshold\_pct="80" display="1" />

<UGA id="13" name="Cottage Grove" city\_center\_E="495544" city\_center\_N="4848939" threshold\_pct="80" display="1"/>

<UGA id="22" name="Eugene-Springfield" city\_center\_E="493716" city\_center\_N="4878556" threshold\_pct="80" display="1" />

<UGA id="39" name="McMinnville" city\_center\_E="484906" city\_center\_N="5006456" threshold\_pct="80" display="1" />

<UGA id="40" name="Metro" city\_center\_E="524352" city\_center\_N="5016976" threshold\_pct="80" display="1"/>

<UGA id="47" name="Newberg" city\_center\_E="503066" city\_center\_N="5016976" threshold\_pct="80" display="1" />

<UGA id="51" name="Salem-Keizer" city\_center\_E="497971" city\_center\_N="4975491" threshold\_pct="80" display="1" />

<UGA id="71" name="Woodburn" city\_center\_E="511107" city\_center\_N="4999241" threshold\_pct="80" display="1" />

</UGAs>

</UGA\_expansion>

</ww2100>

</envision>

Appendix B. Specification for population growth model

from document file “Popupation growth specifications\_DB and AP\_072513.doc”

Dan Bigelow, Andrew Plantinga

07/25/13

Spec for population growth model

The attached spreadsheet, ‘pop\_UGB\_RR\_072513.xlsx’, contains both the UGB and RR population projections at five-year intervals out to 2100. A linear interpolation can be used to derive yearly population estimates for the years within each interval.

Population for each UGB is used to compute the population density for the UGB as [total population of UGB / total area of “developed,” “privately-owned” IDUs in the UGB]. This UGB-level density is should be thought of as an IDU attribute because it enters into the formula for economic returns to urban uses (see “Calculating economic returns for each IDU.pdf”). In particular, urban returns are a function of the population density of the nearest UGB area with 2010 population greater than 20,000. The rest of this document explains how the UGB and RR population data should be linked to IDUs for UGB and RR areas.

Connections with land-use transition model

The land-use transition mechanism described elsewhere (Land-use transitions\_zoning\_UGBs.pdf) will dictate that certain privately-owned undeveloped IDUs within a given UGB are to be converted to a developed use. Once an undeveloped IDU is converted, the population density of the UGB should be recalculated to account for this addition to the overall developed area within the UGB. Further, the way in which the UGB-level population is allocated to IDUs should reflect this newly generated UGB-wide density. Specifically, if IDU i is converted to development, the population density of UGB j should be calculated as [total population of UGB j / (previous total developed area of UGB j + area of IDU i)].

One area that adds some complexity to the coupling of the land-use transition and population data stems from UGB expansions into RR areas.[[1]](#footnote-1) RR areas, by definition, have a non-zero population, unlike the undeveloped IDUs within UGBs. When a UGB expands into an RR area, the existing population of the IDU should be added to the current UGB-level population and subtracted from the corresponding RR area. Note that this newly incorporated IDU within the UGB (formerly within an RR area) may not be developed immediately, and so its land area should only be added to the developed land area of the UGB when development occurs. Increases in population of the UGB should, again, be allocated in the way described above.

IDU attributes needed

Given the relatively large number of rural residential and UGB areas in the WRB study area, it seems that the easiest way to implement the population growth model would be to link the IDUs to a spreadsheet file that contains the relevant UGB and RR population projections. In addition to the attached spreadsheet (‘pop\_UGB\_RR\_072513.xlsx’), an additional spreadsheet will be created and added to the existing IDU attribute table. This sheet will contain five IDU attributes needed for the population growth model: (1) unique IDU index, (2) a binary variable indicating if the centroid of a given IDU falls within a UGB, (3) for IDUs inside of UGBs, an ID for the UGB so that the IDU attributes can be linked to the population data file, (4) a binary variable indicating if the centroid of a given IDU falls within an RR area, and (5) for IDUs within RR areas, an ID for the RR area so that the IDU attributes can be linked to the population data file.

One final complication that will need to be addressed again deals with the notion of incorporating previously RR IDUs into a UGB. When an RR IDU becomes incorporated into a UGB, the attributes of that IDU will need to be adjusted accordingly. Specifically, the binary RR indicator (formerly a ‘1’) will need to be switched to ‘0’, and likewise the UGB indicator (formerly a ‘0’) will become ‘1’. Further the relevant RR and UGB ID #’s will need to be altered. Specifically, the RR ID # will take a null value and, as necessary, the UGB ID # should be changed to reflect the UGB of which the IDU is now a part.

Appendix C. Implementation plan for the population growth model

Implementation plan for the WW2100 population growth model

Dave Conklin 7/28/13 1800 rev. 8/3, 8/27

"Complete and final" on 7/31/13 per Bill Jaeger pers. comm. and Andrew Plantinga's email to Dave Conklin on 7/30 "Re: Population Growth model spec"

References:

1) spreadsheet file “pop\_UGB\_RR\_072513.xlsx”

2) spreadsheet file “IDU\_UGB\_RR\_072913.xlsx”

3) document file “Popupation growth specifications\_DB and AP\_072513\_2.doc”, from Dan Bigelow and Andrew Plantinga, with sections titled “Spec for population growth model”, “Connections with land-use-transition model”, and “IDU attributes needed”

The first spreadsheet provides population projections at 5 year intervals from 2010 thru 2100 for 67 urban areas defined by urban growth boundaries (UGBs) and 915 rural areas. Here I will refer to the urban areas as UGAs and the rural areas as “RPAs” (rural population areas), and use the term “population unit” for both UGAs and RPAs. As used here, “rural” means “outside all UGAs”, and “urban” means “within a UGB”. By definition, at any one time an IDU may be associated with either a UGA, or an RPA, or with neither one, but not with both a UGA and an RPA. Per Dan Bigelow, the model implementation may regard any given IDU as either entirely within an RPA or entirely outside of all RPAs.

Dan Bigelow provided a second spreadsheet with rows for all the IDUs (~172,000 rows). From the second spreadsheet it is possible to determine, for any rural IDU, whether or not it is part of an RPA, and if so, which one. The second spreadsheet also identifies the UGA for each urban IDU. There may be differences between the what the existing “UGB” attribute says about which IDU is in which UGB and what the second spreadsheet says. Those differences should be resolved by reference to the appropriate government map. Resolving those differences is a task for Dan Bigelow and Andrew Wentworth. The second spreadsheet designates a significant fraction of IDUs as being outside all of the UGAs and RPAs.

For the purpose of this document, I’ll assume that we add “RPA” as an attribute to the IDU database. Note that since an IDU can only be in one or the other of a UGA or RPA but not both, the UGB and RPA attributes could be encoded into a single integer attribute, but for clarity here I’ll refer to them as separate attributes.

As noted in the spec for the population growth model, during WW2100 simulations a different model, the UGB expansion model, may put additional IDUs within UGBs. When that happens, it will update the IDU’s UGB and RPA attributes appropriately. Since the newly added IDU may be populated (POP attribute > 0) but “undeveloped” (e.g. LULC\_A attribute is “Agriculture” or “Forest” rather than “Developed”), the UGB expansion process will, in general, create populated but undeveloped areas within the UGB.

Another different model, the land-use transition model, will change the use of some rural IDUs from forestry or agriculture to developed, but per Dan Bigelow it will not affect the status of the IDU relative to the RPAs. Dan also confirmed my assumption that, although IDUs may be added to UGAs, no wholly new UGAs or RPAs will be created during a simulation.

The ref. 1 spreadsheet specifies population projections in units of number of people at

5-year intervals for all the UGAs and RPAs. The model calls for the calculation of a population density value for each such population unit. For the purpose of calculating population density from population for RPAs, the area of the RPA will be taken as the sum of the AREA attributes of the IDUs in the RPA. The population density for UGAs, however, has a more elaborate definition. Per the spec, the population density of the UGA is

“total population of UGB / total area of “developed,” “privately-owned” IDUs in the UGB”. The value of the denominator will be found by summing the AREA attributes of IDUs for which the UGB attribute is the target UGA, the LULC\_A attribute is “Developed”, and the OWNER attribute is = “Private”. Note that the resulting value for area will usually be significantly less than the total area within the UGB, since by definition UGBs are intended to encompass land which has not yet been developed. The numerators in the density calculations for RPAs and UGAs will be taken from the ref. 1 spreadsheet, with linear interpolation if necessary for intermediate years. Note that the spec calls for linear interpolation, not constant growth rate interpolation.

Because there will in general be populated but undeveloped IDUs within a UGA, whose population is included in the numerator, but whose area is excluded from the denominator of the population density expression in the spec, the UGA population density as specified will be greater than the figure which would be obtained from dividing the total population in the UGA by the total area of the UGA, the usual way of calculating density. To avoid confusion, here I’ll use “adjusted UGB population density” to refer to the population density as specifed.

The population growth model will be implemented as a subprocess, “popGrowth”, of the WW2100AP autonomous process plugin for Envision. An example of the portion of the XML file used by WW2100AP which pertains to popGrowth is given later below.

The ref. 1 spreadsheet has two pages, “UGB” and “RR”. Column A on both pages has an identifying number for the associated population unit; on the UGB page, the column A heading is “UGB\_DH\_ID”, while for the RR page it is “RR\_DH\_ID”. I imagine “DH” refers to Dave Hulse. All the ID numbers for UGB are 4 digit non-zero positive integers in the range 1022-1088, inclusive; for the RR page, the ID numbers are in the range 67-981, inclusive. There are fewer UGB ID numbers than there are UGB values in the WW2100 IDU.xml; nevertheless, I assume that the UGBs for which population is prescribed in the spreadsheet correspond spatially to similarly-named UGBs in the WW2100 IDU layer, and that the existing “UGB” IDU attribute can be used to associate the appropriate line in the spreadsheet with urban IDUs. I will create a crosswalk between the integer values in the UGB attribute and the UGB ID numbers in the spreadsheet, based on the UGB names. That process will identify which UGBs don’t correspond in the WW2100 IDU database and the ref. 1 spreadsheet. Resolving those discrepancies is a task for Dan Bigelow and Andrew Wentworth.

The spreadsheet is in Microsoft Excel format. I’ll use Excel to store each page of the spreadsheet in .csv (comma-separated values) format. The two resulting files, here called UGBpop.csv and RRpop.csv, will be input data for the model in Envision.

Example WW2100AP XML file

<envision> <ww2100>

...

<popGrowth in\_use=1 ruralPopUnitCol=“RPA” urbanPopUnitCol=”UGB” >

<popGrowthFiles

UGBpop\_file = “/Envision/StudyAreas/WW2100/AppliedEconData/UGBpop.csv”

RRpop\_file = “/Envision/StudyAreas/WW2100/AppliedEconData/RRpop.csv”

/>

</popGrowth>

</ww2100> </envision>

The popGrowth subprocess will produce outputs for each UGA having a 2010 population of >20,000 and for each county which overlaps the WW2100 study area. For those UGAs, for each year, popGrowth will output population totals and adjusted population densities. For each county for each year, popGrowth will output a single population number representing the sum of the populations of all the RPAs in the county.

Current-year adjusted population densities for UGAs with 2010 populations of >20,000 will be kept as member data of the WW2100AP process (~8 floating point numbers). As such, that data will be accessible to other applied economics models (e.g. the urban return calculation in the land-use transition model). An IDU attribute will be created which identifies the nearest such UGA (~172,000 short integers). The use of the short integer UGA identifier rather than the floating point adjusted population density as an IDU attribute saves a substantial amount of storage space.

In each annual timestep, the popGrowth subprocess will:

- look up or interpolate the prescribed populations for the UGAs and RPAs

- determine the areas of the RPAs, from summing the AREA attributes of the IDUs in the RPAs

- calculate the population density of each RPA, by dividing the prescribed population for the RPA by the total area of the RPA

- for each IDU in every RPA, store the RPA’s population density into the IDU’s POPDENS attribute, and calculate a new value for the IDU’s POP attribute equal to the product of POPDENS and AREA, rounded to an integer

- for each county, calculate the total population of the RPAs in the county (note that this number may be smaller than the total rural population of the county, since some rural IDUs may be populated but not part of any RPA)

- determine the total area of developed (LULC\_A attribute = “Developed”), privately-owned (OWNER attribute = “Private”) land in each UGA

- calculate the adjusted population density of each UGA, by dividing the prescribed population for the UGA by the total area of developed, private land in the UGA

- determine the total population within the portion of each UGA which is either undeveloped or not privately-owned or both, here called the “legacy population” since it is not produced by the population growth model

- for each UGA, calculate a new value for the POPDENS attribute of developed, privately-owned IDUs, as

(prescribed UGA population - UGA legacy population)/(area of developed, private land)

- calculate and store a new value for the POP attribute of each IDU in the developed, privately-owned portion of every UGA, as the product of the IDU’s POPDENS and AREA attributes

Missing information

At this time, I am not aware of any additional information that I need to implement the population growth model on Envision, assuming agreement can be obtained that the spec, the 2 spreadsheets, and this implementation description are “complete and final”. However, I believe there is work for Dan Bigelow and Andrew Wentworth to reconcile the UGB and POP columns in the WW2100 IDU database with the ref. 2 spreadsheet.

As-built notes, added after "complete and final" agreement was reached on 7/31/13

1. Add coldstart logic to WW2100AP:

- read the second spreadsheet

- populate an RPA attribute

- check that IDUs in RPAs are zoned RR

- check that IDUs in UGAs in the spreadsheet have consistent UGB values in the database

7/31/13

2. Use the modeler plugin, instead of the popGrowth code in the WW2100AP plugin, to output the UGB population time series for the 8 most populous UGBs, and to output the the RPA population time series for each county that has RPAs. There are no RPAs in Douglas, Lincoln, Tillamook, Columbia, Deschutes, or Wasco counties. Here is the entry for modeler in the .envx file, and the associated .xml file:

from the .envx file

<autonomous\_process

name ='PopReport'

path ='Modeler.dll'

id ='100'

use ='1'

timing ='1'

freq ='10'

sandbox ='0'

fieldName =''

initInfo ='/Envision/StudyAreas/WW2100/wv\_modeler\_Econ.xml'

dependencies =''

initRunOnStartup ='0'

/>

</autonomous\_processes>

the wv\_modeler\_Econ.xml file

<modeler>

<auto\_process name="Population Report" id="100" value="" >

<report name="Metro UGB pop" query="UGB=40" value="POP" type="sum" />

<report name="Eugene/Springfield UGB pop" query="UGB=22" value="POP" type="sum" />

<report name="Salem UGB pop" query="UGB=51" value="POP" type="sum" />

<report name="Corvallis UGB pop" query="UGB=12" value="POP" type="sum" />

<report name="Albany UGB pop" query="UGB=2" value="POP" type="sum" />

<report name="McMinnville UGB pop" query="UGB=39" value="POP" type="sum" />

<report name="Newberg UGB pop" query="UGB=47" value="POP" type="sum" />

<report name="Woodburn UGB pop" query="UGB=71" value="POP" type="sum" />

<report name="BentonCo RPApop" query="COUNTYID=1 AND RPA>0" value="POP" type="sum" />

<report name="ClackamasCo RPApop" query="COUNTYID=2 AND RPA>0" value="POP" type="sum" />

<report name="LaneCo RPApop" query="COUNTYID=4 AND RPA>0" value="POP" type="sum" />

<report name="LinnCo RPApop" query="COUNTYID=6 AND RPA>0" value="POP" type="sum" />

<report name="MarionCo RPApop" query="COUNTYID=7 AND RPA>0" value="POP" type="sum" />

<report name="MultnomahCo RPApop" query="COUNTYID=8 AND RPA>0" value="POP" type="sum" />

<report name="PolkCo RPApop" query="COUNTYID=9 AND RPA>0" value="POP" type="sum" />

<report name="WashingtonCo RPApop" query="COUNTYID=11 AND RPA>0" value="POP" type="sum" />

<report name="YamhillCo RPApop" query="COUNTYID=12 AND RPA>0" value="POP" type="sum" />

</auto\_process>

</modeler>

8/3/13

3. Simplify the portion of the WW2100AP .xml file associated with popGrowth, by eliminating the the <popGrowthFiles ... > tag. Here is the current version:

<popGrowth in\_use="1" ruralPopUnitCol="RPA" urbanPopUnitCol="UGB"

UGBpop\_file="/Envision/StudyAreas/WW2100/ARECmodels/UGBpop.csv"

RRpop\_file="/Envision/StudyAreas/WW2100/ARECmodels/RRpop.csv"

/>

8/3/13

4. Add the files used by the popGrowth model to the Envision repository:

- Envision/StudyAreas/WW2100/ARECmodels/RRpop.csv and .../UGBpop.csv, derived from pop\_UGB\_RR\_072513.xlsx, version 5025

- Envision/StudyAreas/WW2100/ARECmodels/ IDU\_UGB\_RR\_072913.csv, derived from a .xlsx file of the same name, version 5025

- /Envision/StudyAreas/WW2100/wv\_modeler\_Econ.xml, version 5026

- /Envision/StudyAreas/WW2100/WW2100\_Econ.envx, version 5028

8/3/13

5. Update existing files in the Envision repository:

- Envision/src/WW2100AP/WW2100AP.cpp, .h, version 5024

- Add and populate the RPA attribute to /Envision/StudyAreas/WW2100/IDU.dbf, version 5005, derived from IDU\_UGB\_RR\_072913.csv

- /Envision/StudyAreas/WW2100/WW2100AP\_ColdStart.xml, version 5027

- /Envision/StudyAreas/WW2100/WW2100AP.xml, version 502918

8/3/13

Appendix D. Crop choice model

Human System Model Component #3 – Crop Choice Model

Bill Jaeger and Dave Conklin

Date: July 30, 2013 rev 8/11. Modified 8/16, 8/19. Modified accept changes 8/20. Modified Feb 28, 2014. Modified: modified 08/14/2014 (DB)

This model estimates the probability that a given crop will be grown on an IDU in a given year. The model will implement these probabilistic functions using a “random draw” to determine which crop is grown each year. Crop choices are uncorrelated across years. The crop choice depends on factors such as soil class (LCC), water rights, and other attributes related to the parcel’s location (e.g., elevation, slope, average temperature and average precipitation), and crop prices.

1. Crop choice probabilities

Pj = β0 + β1LCC1 + β2LCC2 + β3LCC3 + β4LCC4 + β5LCC5 + β6LCC6 + β7LCC7

+ Β8EL + β9SL + β10PR + β11MT + β12PG + β13PW + β14(IR\*SE)

for j = 1 to 8 where 8 = “other crops”

where Pj = the probability of choosing crop j

LCC1 to LCC7 is the dominant land capability class in the IDU (X1 to X7)

EL = elevation (in meters, demeaned by subtracting 97.2) (X8)

SL = slope (demeaned by subtracting 3.704) (X9)

PR = growing season average total precipitation (inches; demeaned by subtracting basinwide 30-year mean growing season total precipitation; updated in each time step) (X10)

MT = min. temp. for growing season (degrees C, demeaned by subtracting basinwide 30-year mean growing season minimum temperature; updated in each time step) (X11)

PG = price of grass seed (Initially assume fixed price at $64/ton) (X12)

PW = price of wheat (Initially assume fixed price at $5/bushel) (X13)

IR = irrigation water right (1 if a water right exists, otherwise 0) (part of X14)

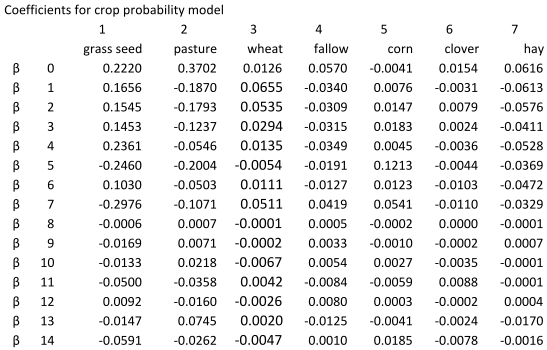
SE = 1 if the April 1 snowpack measure is greater than or equal to the average snow pack in the previous 10 years. (SE denotes expected snow.) (part of X14)

SE = (1- SH) if the April 1 snowpack measure is below the average snow pack in the

previous 10 years, where SH is the frequency in the past 10 years that this water right has been shut off at any point during a season in order to protect other senior water rights (Range of DN = 0 to 1, initial value is 0 for all IDUs). (SH denotes shut off history.) (part of X14)

IDUs that are permanently cropped in orchards/vineyards are listed in the Excel file, orchardIDU.

The coefficients for this equation are listed in the table below:



To avoid some anomalies when these estimated probabilities are applied to the IDUs, some limits need to be imposed individually for each crop, and then collectively (to ensure that 0<Pj<1, individually and when totaled). To do this, the individual crop probabilities Pj will be adjusted to P’j as follows:

Step 1: If then set

Step 2: If then set

Step 3: If then and for 1,…,7

Step 4: If then

Finally, if farmland rent < $1, crop = fallow.

1. Crop choice adjustments for IDUs with water rights

The model above for crop choice takes account of the IDU irrigation water right, and also if exercising the water right is denied by the water master. It does not, however, include any change in cropping probabilities in years when the IDU is irrigated as opposed to years when the irrigator chooses not to irrigate (which has about a 30% probability in the irrigation choice model when the grower has the option to irrigate).

We want to adjust the crop choice probabilities (for an IDU with water rights) to reflect to some extent the decision in a given year to irrigate or not to irrigate.

For an IDU in year t, following the random draw that determines IRR= 1 or 0 (whether the IDU will be irrigated or not in year t), the only effects of this irrigation decision on crop choice will be as follows:

If IRR = yes, probability (fallow) = 0,

If IRR = yes, probability (wheat) = 0,

If IRR = no, probability (corn) = 0

If farmland rent <$1, IRR = no, crop = fallow. (This may be redundant with other specs.)

As a result of these adjustments for fallow, wheat and corn, the probability of “other crops” (j =8 ) is adjusted to compensate since this probability is defined as

III. Implementation of the Crop Choice model in Envision

The crop choice model will be implemented as part of the WW2100AP plugin, similarly to other human system models such as the irrigation choice and farmland rent models. An example of the associated XML text is given below. Coefficient values, instead of being in the XML text as for the irrigation choice and farmland rent models, are read in from a comma-separated-values (.csv) file generated from an Excel spreadsheet, "Worksheet in WW2100\_Models\_Crop\_Choice\_July\_30\_DRC.xlsx". This spreadsheet file is based on the file associated with the coefficient table in part I above.

The crop choice subprocess will run at the beginning of the annual timestep, but after the irrigation choice model is run.

Example of XML text for crop choice model:

<ww2100 tau\_climate="30" tau\_WR="10" >

...

<crop\_choice in\_use="50" test\_mode=”0” coefficients\_file="cropchoice.csv" >

<time\_dependent\_datasets>

<time\_dependent\_data symbol="PG" description="price of grass seed, $/ton"

method="timeseries\_linear" value="(2010, 64.), (2100, 64.)" />

<time\_dependent\_data symbol="PW" description="price of wheat, $/bushel"

method="timeseries\_linear" value="(2010, 5.), (2100, 5.)" />

<time\_dependent\_data symbol="snowpack" description="regional snowpack on Apr 1"

method="file" value="MC2data/MIROCsnowpack.csv" />

</crop\_choice>

</ww2100>

Example of cropchoice.csv file, from "Worksheet in WW2100\_Models\_Crop\_Choice\_July\_30\_DRC.xlsx":

beta,grass seed,pasture,wheat,fallow,corn,clover,hay

0,0.221989,0.3702331,0.0126356,0.0569527,-0.0041204,0.0154454,0.0616335

1,0.1655975,-0.1869973,0.0654987,-0.0339811,0.0075938,-0.003053,-0.0613196

2,0.1544618,-0.1792509,0.0534677,-0.0309153,0.0147065,0.0078914,-0.0576372

3,0.1452702,-0.1237006,0.0293751,-0.0315311,0.018316,0.0023917,-0.0411414

4,0.2360827,-0.0546424,0.0135087,-0.0349058,0.0044719,-0.0035872,-0.0528224

5,-0.2459707,-0.2003965,-0.0054098,-0.0190955,0.1213284,-0.0043517,-0.0369339

6,0.1029519,-0.0503389,0.0111162,-0.012661,0.0123436,-0.0103205,-0.0472421

7,-0.2976381,-0.1071058,0.0510725,0.0418892,0.0540705,-0.0110277,-0.0328851

8,-0.0006327,0.0007376,-0.000065,0.0004684,-0.0001566,-0.000024,-0.0000533

9,-0.0169293,0.0070737,-0.0002278,0.0033235,-0.0010188,-0.0002214,0.0006709

10,-0.0133127,0.0218101,-0.0067494,0.0054416,0.0027304,-0.0034812,-0.0000655

11,-0.0500331,-0.0357901,0.0042469,-0.0083876,-0.0058614,0.0087592,-0.0000677

12,0.0092116,-0.0159899,-0.0026069,0.008041,0.0002577,-0.0001575,0.0004473

13,-0.0146539,0.0744832,0.0019551,-0.0124758,-0.0040865,-0.002382,-0.0169719

14,-0.0590991,-0.026179,-0.0047208,0.0010465,0.0185157,-0.0077776,-0.0015602

Most of the independent variables are shared with other human systems models, but three, the prices of grass seed and wheat and the April 1 snowpack, are new in this model. The shared independent variables are:

IDU attributes

LCC - land capability class, 0-8

ELEV - mean elevation of the IDU, meters ASL

SLOPE\_DEG - mean slope of the IDU in degrees from horizontal

WREXISTS - 0 for no water right, 1 for groundwater, 2 for surface water, 3 for both

WR\_SH\_NDX - water right shutoff history

FRMRNT\_LR – long term farmland rent

Gridded climate data

growing season precipitation, in mmH2O converted to inH2O

growing season mean diurnal minimum temperature, deg C

The three new independent variables will be supplied as "time\_dependent\_datasets" in the XML text. The prices can be specified explicitly in the XML text itself, while the snowpack data is more conveniently supplied as a .csv file.

The output of the crop choice model on Envision will be, for each IDU in the LULC\_A Agriculture and Other Vegetation classes, an integer LULC\_C value denoting one of 9 possibilities:

80 orchards/vineyards

81 grass seed

82 pasture

83 wheat

84 fallow

85 corn

86 clover

87 hay

88 other crops

The LULC\_B value will be changed along with the LULC\_C value, in keeping with the LULC hierarchy. For these 9 classes, the LULC\_B and LULC\_C integer values are the same. In WW2100 Envision, the LULC\_C attribute is named “VEGCLASS”. All except one (fallow) of these 9 classes are subdivisions of the LULC\_A Agriculture land use; fallow is a category of the LULC\_A Other Vegetation land use.

As with the Irrigation Choice model, a test\_mode attribute has been added to the XML text for the Crop Choice model. 15. When the test\_mode attribute is set to 1, the model creates IDU attributes for each independent variable value and for the sum of the betaX terms, and for the calculated probability. The betaX sum for the chosen crop is saved. These values can be used to confirm that the model is working as specified. Only one model’s test mode data can be saved in a single simulation.

Appendix E. Irrigation decision model

Irrigation Choice Model in WW2100 model

Bill Jaeger and Dave Conklin Date: July 31, 2013 "Complete and final" on 7/31/13

As-built section added 8/5, rev. 8/8 Final Changes Accepted 8/16/13 Additional as-built notes 8/18.

Rev 8/20 to accept changes.

This model estimates the probability that an IDU with a water right will be irrigated or not in a given year. The model is implemented as a “random draw” to determine if the grower irrigates each year. Decisions are uncorrelated across years. The outcome is also dependent on whether an irrigation “shut off” occurs. If the grower’s decision is to NOT irrigate, and water is shut off, there is no effect on short-term farmland rent. This shut-off will, however, affect long-run farmland rent.

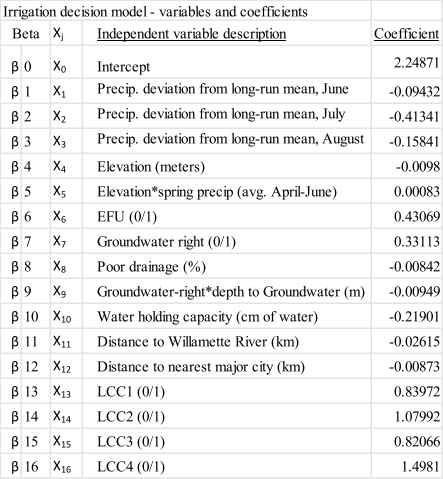
1. Decision to irrigate an IDU– probability of irrigating

The model is estimated as:

Ln(PIRR/(1-PIRR)) = β0 + β1X1 + β2X2 + β3X3 + β4X4 + β5X5 + β6X6 + β7X7 + β8X8 + β9X9

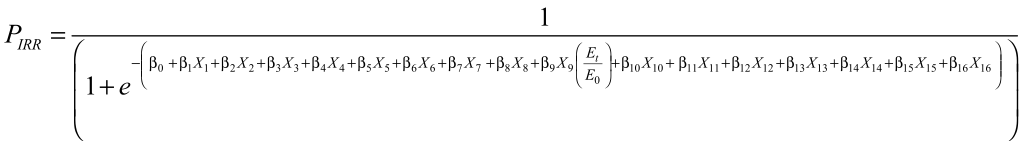
+ β10X10 + β11X11 + β12X12 + β13X13 + β14X14 + β15X15 + β16X16

Where the Xis, βjs are defined in the table below (double click to open as Excel table):



And where Et/E0= is the ratio of the (index of) energy price in year t to the energy price initially. Et is assumed to equal E0  for the reference case scenario. Initially assume Et = E0=1. This term is intended as a “place holder” for an alternative scenario in which energy prices rise (in real terms)

Probability of irrigating is estimated as follows:



Also, if farmland rent < 1, PIRR = 0

1. Implementation of the Irrigation Choice model in Envision

The irrigation choice model will be implemented as a subprocess of the WW2100AP autonomous process plugin, running at the beginning of each annual simulation timestep. Input parameters will be supplied in the XML file used by WW2100AP. Each of the 16 beta coefficients will default to the values given in the table above; individual values may be adjusted by specifying them in the XML file. The Et/E0 ratio will default to 1 but may be specified as a time series of relative energy prices, as in this example XML file[[2]](#footnote-2):

<envision> <ww2100>

<Coldstart ... </Coldstart>

<fish ... </fish>

<carbon ... </carbon>

<agtrans ... </agtrans>

<urbanwater ... </urbanwater>

<DGVMvegtypeData ... </DGVMvegtypeData>

<irrigation\_choice in\_use='1' tau='30'>

<coefficients>

<coefficient symbol='beta0' value=' 2.24871' description='intercept' />

<coefficient symbol='beta1' value=' -0.09432' description='Precip dev, June' />

...

<time\_dependent\_coefficient symbol='Eyr' method='timeseries'

value='(2010,1),(2100,1)' />

</coefficients>

</irrigation\_choice>

<popGrowth ... </popGrowth>

</ww2100> </envision>

The irrigation choice model will be run for all IDUs which satisfy this query:

LULC\_A = 2 {Agriculture} or LULC\_A=3 {Other vegetation}

The irrigation choice is set immediately to 0 (no irrigation) if there are no water rights or the long-term farmrent is <$1/acre. Otherwise, the model produces a probability. The probability will be converted to a binary yes-or-no choice by comparing a random draw from the unit interval with the calculated probability. When the random draw is less than[[3]](#footnote-3) the calculated probability, the outcome is a decision in favor of irrigating, otherwise, the outcome is against irrigation. The decision is stored in the IRRIGATION attribute using the AddDelta() method, coded 1 for yes and 0 for no.

Independent variable values, except relative energy prices, are based on IDU attributes and gridded data as follows:

x1, x2, x3 gridded monthly precipitation data, converted from mmH2O to inH2O

x4 ELEV, m

x5 ELEV, gridded monthly precipitation data, converted to inH2O

x6 EFU, exclusive farm use, 0/1

x7 WREXISTS (WREXISTS=1 or 3 for groundwater right)

x8 DRAINAGE, % poor drainage

x9 WREXISTS, D\_GWATER, depth to groundwater, m

x10 AWS, available water storage

x11 D\_WRIVER, distance to the Willamette R., km

x12 D\_CITY, distance to nearest major city, km

x13-x16 LCC, land capability class

The energy price ratio, Et/E0 , will be calculated in each annual simulation timestep by dividing the current year value of Eyr timeseries by the value for the first year[[4]](#footnote-4) of the simulation.

Some of the necessary IDU attributes already exist in the WW2100 IDU database: ELEV, LCC. Others remain to be added:

EFU - "exclusive farm use" zoning, a boolean variable, will be drawn from an EFU .tiff file provided by Alexey Kalinin

WREXISTS - a categorical variable with four values (0=no water right, 1=groundwater water right, 2=surface water right, 3=both surface and groundwater water rights), from data to be provided by James Sulzman

DRAINAGE - a continuous variable in units of % denoting "poor drainage", from a .tiff file provided by Alexey Kalinin

D\_GWATER - "depth to groundwater", from a shape file provided by Roy Haggerty, with interpretation by Alexey Kalinin

AWS - "available water storage", from a shape file provided by Alexey Kalinin

D\_WRIVER - "distance to Willamette River, km", to be provided by Alexey Kalinin

D\_CITY - "distance to nearest major city, km" - to be provided by Alexey Kalinin. Major cities are Portland, Salem, Eugene, Springfield, Corvallis.

Andrew Wentworth and Dan Bigelow are working to incorporate the new attribute data into the WW2100 IDU.dbf file, from the data layers provided by other project participants.[[5]](#footnote-5)

Gridded monthly precipitation data will be read from a netCDF file, prepared off-line from the same set of daily precipitation data used by the Flow plugin. Although the irrigation choice model requires precipitation values for only the months of April thru August, the netCDF files will include a continuous monthly time sequence. In addition, long term monthly mean values are required, in order to calculate the deviations from the long term means (x1, x2, x3). The initial values of the long term monthly means will be calculated off-line or in the Cold Start subprocess of WW2100AP[[6]](#footnote-6). During the simulation, the long term mean will be updated each year using

mean\_val = prev\_mean\_val\*exp(-1/tau) + new\_raw\_val\*(1 - exp(-1/tau))

The default value of tau, and the value for use in calculating the initial state of the long term means[[7]](#footnote-7), is 30. The initial state of the long term means will be calculated for the 30 year period prior to 2006, i.e. 1976-2005. Monthly time series of precipitation data will start in January, 1976, or January of an earlier year.

The precipitation data has units of mmH2O. It will be converted to inH2O before use with the coefficient values given above. Precipitation deviations will be calculated as this year's value minus the long-term mean.

During a simulation, arrays holding the mean values for each grid cell will be kept as data of the WW2100AP process. At each annual timestep, the current value of the variable for each grid cell will be read from the netCDF file and used first to calculate the deviation and then to update the mean value. The 4km grid for the WW2100 study area has 63 rows and 51 columns, for a total of 3213 grid cells[[8]](#footnote-8), a far smaller number than the number of IDUs (~172,000), so storing the precip data internally by grid cell rather than by IDU uses less memory.

As-built notes, added after "complete and final" agreement was reached on 7/31/13

1. Linear interpolation should be used in interpreting the time sequence for relative energy costs in the XML file. 7/31

2. I added the path and file name of the precip data to the XML file, and moved the time\_dependent\_ccoefficient tag outside of the <coefficients> block. Here is the XML file that I'm using for initial testing:

(see XML with note 11 below, 8/18/13 )

8/5/13

3. I added total irrigated acres as an output variable to the same Modeler instance as I'm using for population outputs. Here is an excerpt from the wv\_modeler\_Econ.xml file showing the addition for irrigated acres:

(see XML with note 12 below, 8/18/13 )

8/5/13

4. I changed the sense of the decision based on the random draw. Now, when Pirr>the random draw, the decision is to irrigate, and when Pirr<=the random draw, the decision is to not irrigate.

8/5/13

5. A specification of the Et/E0 energy price index time series is required in the XML file, using the <time\_dependent\_coefficient symbol='Eyr' .../> tag, as illustrated in the sample XML file in note #2 above. (see XML with note 11 below, 8/18/13 )

8/5/13

6. Instead of calculating the initial values of the long term means for the precip values in the cold start subprocess, they are calculated in the initialization phase of the Irrigation Choice subprocess itself. This change allows for switching climate datasets without having to rerun the coldstart process.

8/8/13

7. tau defaults to 30, but its value can be changed in the XML file. When the long term precip means are initialized, if there are fewer than tau years of prior data available, then the code just uses however many years of prior data are available. In that case, a message is written to the log file to alert the user.

8/8/13 (See also note 13 below, 8/18)

8. While a grid of 63 rows and 51 columns does cover the WW2100 study area, by convention we actually use a grid that extends out 3 gridcells farther on all sides, increasing the grid size to 69 rows by 57 columns, and increasing the number of cells from 3213 to 3933.

8/8/13

9. Observing that 10 or possibly 11 of the 16 independent variables are not time-dependent, it would be possible to speed up the execution of the model somewhat by calculating the sum of the terms involving those variables just once at the beginning of a simulation, rather than doing it in every timestep. However, at the moment, the Irrigation Choice submodel seems to run pretty fast even without that speedup.

8/8/13

10. I have added attributes to the WW2100.dbf file for WREXISTS, DRAINAGE, D\_GWATER, AWS, D\_WRIVER, and D\_CITY, and populated them with placeholder values.

8/8/13 (See note 14 below 8/18).

11. Here is new sample XML text for the WW2100AP file. Note “tau\_climate” and “tau\_WR” in the third line, the Eyr specification starting in line 4, and the <climate\_files> tag in line 6. These apply to all the AREC models. In the block for Irrigation Choice, note the test\_mode attribute; see note 15 below for a description of test mode.

<?xml version="1.0" encoding="utf-8"?>

<envision>

<ww2100 tau\_climate="30." tau\_WR="10." >

<time\_dependent\_coefficient symbol="Eyr" method="timeseries\_linear"

value="(2010,1), (2100,1)" description="energy cost index time series" />

<climate\_files

precip\_filename ="/Envision/StudyAreas/WW2100/ARECmodels/MIROC5ppt.nc"

tmin\_filename ="/Envision/StudyAreas/WW2100/ARECmodels/MIROC5tmin.nc" />

<ColdStart in\_use ="1" initial\_irrigation\_fraction="0.6" /> ...</ColdStart>

<fish in\_use="0"> ... </fish>

<carbon in\_use='0' > ... </carbon>

<agtrans in\_use='0' > ... </agtrans>

<urbanwater in\_use='0'> ... </urbanwater>

<DGVMvegtypeData in\_use='80' >... </DGVMvegtypeData>

<irrigation\_choice in\_use="50" test\_mode="0" > <!-- s/b in\_use=50 -->

<coefficients>

<coefficient symbol="beta0" value="2.24871" description="intercept" />

<coefficient symbol="beta1" value="-0.09432" description="Precip dev, June" />

<coefficient symbol="beta2" value="-0.41341" description="Precip dev, July" />

<coefficient symbol="beta3" value="-0.15841" description="Precip dev, August" />

<coefficient symbol="beta4" value="-0.0098" description="Elevation (meters)" />

<coefficient symbol="beta5" value="0.00083"

description="Elevation\*spring precip (avg. Apr-Jun" />

<coefficient symbol="beta6" value="0.43069" description="EFU (0/1)" />

<coefficient symbol="beta7" value="0.33113" description="Groundwater right (0/1)" />

<coefficient symbol="beta8" value="-0.00842" description="Poor drainage (%)" />

<coefficient symbol="beta9" value="-0.00949"

description="Groundwater-right\*depth-to-groundwater (m)" />

<coefficient symbol="beta10" value="-0.21901"

description="Water holding capacity (cmH2O)" />

<coefficient symbol="beta11" value="-0.02615"

description="Distance to Willamette R. (km)" />

<coefficient symbol="beta12" value="-0.00873"

description="Distance to nearest major city (km)" />

<coefficient symbol="beta13" value="0.83972" description="LCC1 (0/1)" />

<coefficient symbol="beta14" value="1.07992" description="LCC2 (0/1)" />

<coefficient symbol="beta15" value="0.82066" description="LCC3 (0/1)" />

<coefficient symbol="beta16" value="1.4981" description="LCC4 (0/1)" />

</coefficients>

</irrigation\_choice>

<popGrowth in\_use="80" .../>

<farmland\_rent in\_use="80" tau\_WR="10" > ... </farmland\_rent>

<crop\_choice in\_use="50" ... </crop\_choice>

</ww2100>

</envision>

12. Here is an excerpt of the XML from wv\_modeler.xml which pertains to output from the Irrigation Choice model. Note that, in order for “Approx frac of potential irrigation” output to be correct, the total acreage of ag land with water rights must be entered as the ag\_wi\_WR\_ac constant. That value can be determined in Envision with the query

“LULC\_A = 2 {Ag} and WREXISTS>0”

The number is correct only until land transitions to or from ag and/or water rights change. As of 8/18/13, the data in the WREXISTS column is placeholder data (groundwater rights for every ag IDU), so when WREXISTS is populated with real data, the ag\_wi\_WR\_ac constant will need to be updated. Note the addition of the “Ac of irrigated land from surface WR only” output, per Bill Jaeger’s request on 8/13.

<modeler>

<auto\_process name="EconReport" id="100" value="" >

…

<const name="m2\_per\_acre" value="4046.78" />

<const name="ac\_per\_m2" value="0.00024711" />

<const name="ag\_wi\_WR\_ac" value="1286430" />

<report name="Tot ac of irrigated land"

query="LULC\_A=2 {Ag} and WREXISTS>0 and IRRIGATION=1" value="AREA\*ac\_per\_m2"

type="sum" />

<report name="Approx frac of potential irrigation"

query="LULC\_A=2 {Ag} and WREXISTS>0 and IRRIGATION=1" value="AREA\*ac\_per\_m2/ag\_wi\_WR\_ac" type="sum" />

<report name="Ac of irrigated land from surface WR only"

query="LULC\_A=2 {Ag} and WREXISTS=2 and IRRIGATION=1" value="AREA\*ac\_per\_m2"

type="sum" />

</auto\_process>

</modeler>

8/18/13

13. Now there are two taus, one for climate and one for shutoffs of water rights. They are set in the WW2100AP.xml file, right at the beginning, using tags “tau\_climate” and “tau\_WR”. See the sample XML in note 11.

8/18/13

14. Real data from Dan Bigelow has been used to populate the AWS, D\_CITY, D\_WRIVER, DRAINAGE, and D\_GWATER attributes.

8/18/13

15. When the test mode attribute is set to 1, the Irrigation Choice model creates IDU attributes for each independent variable value and for the sum of the betaX terms, and for the calculated probability. These values can be used to confirm that the model is working as specified. A similar test mode will be implemented for the crop choice model. Only one model’s test mode data can be saved in a single simulation.

8/18/13

16. The manner in which the x1, x2, and x3 variables are calculated was altered and implemented in July, 2014. The specific changes entail that the value with which the current-year’s value is demeaned will not be updated over time. (08/14/14)Appendix F. Farmland rent model

Human System Model Component #2 – Agricultural Land Rents

Bill Jaeger and Dave Conklin Date: July 31, 2013 rev. 8/9. Modified 8/16, 8/19, 8/20

This model estimates the land rent (or net revenue per year) for parcels (IDUs) in agriculture. The ag land rent depends on factors such as soil class (LCC), water rights, and other attributes related to the parcel’s location (e.g., elevation, slope, average temperature and average precipitation). Determinants of land rents will include variables that can change in a scenario: if use of (junior) water right is denied, if cost of groundwater pumping increases due to energy price rise.

1. Expected farmland (long term value) (units in $/acre/year) for an IDU in agriculture

Farm\_RentLR = [1.206 + 104.7\*LCC1 + 95.6\*LCC2 + 69.9\*LCC3 + 66.6\*LCC4 +20.5\*LCC5

+20.5\*LCC6+ 19.9\*LCC7 + (1-SH)\*(1-PC)\*(38.9\*IRR\*LCC1 + 39.1\*IRRLCC2

+ 17.8\*IRR LCC3 + 22.1\*IRRLCC4) – 0.04\*ElevDeMean + 1.37\*PrDeMean + 26.6\*MinTempDeMean] - Cw

where ACRES = size of IDU in acres

LCCj = dummy variables (1/0) for land that is LCC j for j = 1 to 7.

IRR = dummy variable (1/0) if the LCCj parcel has water rights, LCC j for j = 1-4.

ElevDeMean = elevation (in meters, demeaned by subtracting 93.68)

PrDeMean = grow. season avg. precip. (inches, demeaned by subtracting basinwide 30-year mean growing season total precipitation; updated in each time step)

MinTempDeMean = min. temp. for growing season(April-October) in

degrees C (demeaned by subtracting basinwide 30-year mean growing season minimum temperature; updated in each time step)

SH = the frequency in the past 10 years that this water right has been shut off at

any point during a season in order to protect other senior

water rights (Range of DN = 0 to 1, initial value is 0 for all IDUs).

PC = ((Et-E0)/E0)\*(2.0D)\*GW. PC is extra pumping cost; PC =0 initially.

(Et-E0)/E0 is the percent increase in energy price in year t relative to the initial energy price; 2.0 is a placeholder coefficient, D is depth to groundwater. GW=1 if the water right is groundwater, 0 otherwise.

CW = water fee or tax. Initially CW=0, CW may be different for groundwater rights and for surface water rights, or they may be the same. They could be implemented in year T, or gradually increased over some period of years.

There were insufficient observations of LCC5 land in the data to estimate a coefficient. As a result, we are assuming LCC5 lands will be treated as if they have the same value as LCC6 lands.

1. Current farmland rent (short term, current year) (units in $/year) for an IDU in agriculture

Farm\_RentSR = [1.206 + 104.7\*LCC1 + 95.6\*LCC2 + 69.9\*LCC3 + 66.6\*LCC4 + 20.5\*LCC5

+20.5\*LCC6+ 19.9\*LCC7 + (1-SC)\*(1-PC)\*(38.9\*IRR\*LCC1 + 39.1\*IRRLCC2

+ 17.8\*IRR LCC3 + 22.1\*IRRLCC4) – 0.04\*ElevDeMean + 1.37\*PrDeMean + 26.6\*MinTempDeMean] - Cw

where SC = 1 (if water right is shut off in current year; 0 otherwise.) (SC denotes current snow.)

III. Implementation of the Farmland Rent model in Envision

The farmland rent model will be implemented as a subprocess of the WW2100AP autonomous process plugin, running at the end of each annual simulation timestep. Input parameters will be supplied in the XML file used by WW2100AP. Here is an example of the XML file:

<ww2100 tau\_climate="30" tau\_WR=”10” >

<time\_dependent data symbol="Eyr" method="timeseries\_linear"

value="(2010,1), (2100,1)" description="energy cost index time series" />

<climate\_files precip\_filename ="/Envision/StudyAreas/WW2100/ARECmodels/MIROC5ppt.nc"

tmin\_filename ="/Envision/StudyAreas/WW2100/ARECmodels/MIROC5tmin.nc" />

...

<farmland\_rent in\_use="80" >

<coefficients>

<coefficient symbol="a0" value="1.206" description="intercept" />

<coefficient symbol="a1" value="104.7" description="LCC1 (0/1)" />

<coefficient symbol="a2" value="95.6" description="LCC2 (0/1)" />

<coefficient symbol="a3" value="69.9" description="LCC3 (0/1)" />

<coefficient symbol="a4" value="66.6" description="LCC3 (0/1)" />

<coefficient symbol="a5" value="0" description="LCC5 (0/1)" />

<coefficient symbol="a6" value="20.5" description="LCC6 (0/1)" />

<coefficient symbol="a7" value="19.9" description="LCC7 (0/1)" />

<coefficient symbol="a8" value="38.9" description="IRR\*LCC1" />

<coefficient symbol="a9" value="39.1" description="IRR\*LCC2" />

<coefficient symbol="a10" value="17.8" description="IRR\*LCC3" />

<coefficient symbol="a11" value="22.1" description="IRR\*LCC4" />

<coefficient symbol="a12" value="-0.04" description="ElevDeMean" />

<coefficient symbol="a13" value="1.37" description="PrDeMean" />

<coefficient symbol="a14" value="26.6" description="MinTempDeMean" />

<coefficient symbol="a15" value="93.68" description="mean Elev" />

<coefficient symbol="a16" value="13.49"

description="mean growing season precip, inH2O" />

<coefficient symbol="a17" value="8.581" description="mean growing season tmin" />

<coefficient symbol="a18" value="2.0"

description="placeholder coefficient in pumping cost expression" />

</coefficients>

<time\_dependent\_data symbol=”Cw\_groundwater” method=”timeseries\_linear”

Value=”(2010,0), (2100,0)” description=”irrigation H2O cost from groundwater” />

<time\_dependent\_data symbol=”Cw\_surfacewater” method=”timeseries\_linear”

Value=”(2010,0), (2100,0)” description=”irrigation H2O cost from surfacewater” />

</farmland\_rent>

</ww2100>

The farmland rent model will be run for all IDUs which satisfy this query:

LULC\_A = 2 {Agriculture} or LULC\_A=3 {Other vegetation} or LULC\_A=4 {Forest}

The model produces 3 outputs for each IDU in its domain, for each year: a long term expected rent, “FRMRNT\_LR”, a current year rent, “FRMRNT\_YR”, and a time-averaged index of how often the water right is shut off (“WR\_SH\_NDX”), where the names in quotes are the attribute names in the IDU database. For the rents, the units are specified as $/year (but see Missing Information #3 below). For WR\_SH\_NDX, the value is the estimated probability of the IDU’s water right being shut off in any one year, based on the available record of up to tau previous years.

The independent variables are of two kinds, IDU attributes and gridded climate data:

IDU attributes

LCC - land capability class, possible values are 0 thru 8

WREXISTS - water right, 0=none, 1=groundwater, 2=surface, 3=both

D\_GWATER - depth to groundwater

IRRIGATION - the output of the Irrigation Choice model, irrigate=1, don’t irrigate=0

ELEV - mean elevation of the IDU, meters ASL

WR\_SHUTOFF - was the water right shut off in the current year? yes=1, no=0

Gridded climate data

growing season precipitation, in mmH2O which will be converted to inH2O

growing season mean diurnal minimum temperature, deg C

The specification includes a term for the cost of water, CW. CW will be specified as two time-dependent data series, one for IDUs using ground water for irrigation, and one for IDUs using surface water for irrigation. Units are $/acre. The form of the specification in XML text is similar to that used for the relative cost of energy.

The specification describes the “SH” term as “the frequency in the past 10 years that this water right has been shut off at any point during a season to protect other senior water rights”. I propose to calculate the value of SH as a time-averaged mean value of the WR\_SHUTOFF attribute, using the same expression as is used in the irrigation choice model for time-averaging precipitation:

mean\_val = prev\_mean\_val\*exp(-1/tau) + new\_raw\_val\*(1 - exp(-1/tau))

where tau in this case defaults to 10 but is settable as “tau\_WR” in the part of the WW2100AP.xml file which pertains to the farmland rent model. This method of calculating the time-averaged value is preferable to a moving-window average, because it requires storing only a single average value, rather than storing values for each of the time intervals in the window (i.e. rather than storing values for each of the previous 10 years).

Growing season is April thru October, inclusive.

Missing information

1, 2, 3, 4, 5, 7, 9

Resolved 8/16.

10, 11, 12, 14, 15

Resolved 8/20

6. The term in the farmrent expression on the first page which accounts for pumping cost, PC, uses 1-PC as a scaling term to reduce the advantage gained from a groundwater irrigation right as the pumping cost goes up. It seems likely that the intent is to reduce the irrigation right term to 0, but no lower. Should the factor involving PC be written as 1 - min(PC, 1)? Functional form has been corrected.

With the new 8/16 expression for PC, PC can still be greater than 1, which makes (1-PC) negative. Is that what is intended?

8/18/13

I’ll assume that when (1-PC) goes negative, the advantage gained from a groundwater irrigation right should be set to zero, rather than allowed to go negative.

8/20/13

8. The Et/E0 factor in the expression for PC looks like the same one used in the irrigation choice model. Is that so? Assuming that it is, in the XML example on page 2 I have moved the XML tag for relative energy cost (time\_dependent coefficient Eyr) outside the block for the irrigation choice model so that it will apply to any of the AREC models, as needed. Expression has changed, but is still different from the one in the irrigation choice model. Do we need two different time-dependent energy cost data series, or can we use just one, by using Et/E0 in irrigation choice, while using (Et-E0)/E0 in farmland rent?

8/18/13

I’ll assume that we only need one time-dependent energy cost data series.

8/20/13

13. I’ll assume the new 0.5\*LCC5 term should appear in the equation for short term farm rent as well as the one for long term farm rent. 8/18/13

Appendix G. Land use transition and urban growth area expansion models

Implementation of the WW2100 land-use transition model on Envision

Dave Conklin and Dan Bigelow 7/7/13

Model specifications

The land-use transition model for the WW2100 project was developed by Andrew Plantinga and Dan Bigelow. Andrew and Dan have provided two documents as descriptions and specifications of their model, for the purpose of implementing it within the Envision modeling framework:

- “Coding Instructions for land-use transitions, zoning, and UGB expansions in WW2100”, 4 pages, as file “Land-use transitions\_zoning\_UGBs.pdf” attached to Plantinga email to Conklin of 7/1/13, subject “Land-use transitions, UGB expansions, Population and income projections”

- “Documentation for WW2100 land value predictions”, dated 7/1/13, 6 pages, as file “Calculating economic returns for each IDU.pdf” attached to Bigelow email to Plantinga of 7/1/13, subject “Re: Land-use transitions, UGB expansions, Population and income projections”

Land-use transition code in the Envision WW2100 system

The land-use transition model is embodied as a subprocess of the WW2100AP plugin, running near the beginning of each annual timestep. Transition probabilities will be calculated in the first simulation timestep, and recalculated in every fifth annual timestep thereafter. Transitions themselves will be calculated in every annual timestep, using the most recent probabilities. Input parameters are specified as part of the XML file read by WW2100AP. An example XML file is shown below. Conceptually, there are 5 parts to the land-use transition code:

- developed-use values

- agricultural-use values

- forest-use values

- transition probabilities

- transition selection

The first four parts are executed once in every 5 timesteps, while the final part is executed in every timestep.

Developed-use values

The equation for developed-use predicted values has 6 independent variables, listed below with where their values will come from.

UGB attribute UGB

pop\_dens calculate the population density of the 20 UGAs listed on p. 6 of the “... Land Value Predictions” document, using the definition in the footnote on page 1 of the “Coding Instructions...” document

ln\_HH\_inc call a routine in the population growth code (the population growth code will have timeseries data for household income as well as population)

imp = 93.92385, from p. 6 of “...Land Value Predictions” document

citydist new attribute D\_CITY20K

county\_group attribute from attribute COUNTYID

Agricultural-use predicted values

The expression for ag\_val has 7 independent variables:

acres attribute AREA, converted from m2 to acres

slope new attribute SLOPE\_DEG, also needed for at least one other related model

citydist new attribute D\_CITY20K

county\_group attribute from attribute COUNTYID

imp = 57.92065, from p. 6 of “...Land Value Predictions” document

farmrent new attribute FR\_EXPECTD, holding long term farmland rent from the farmland rent model

mean\_imp = 38.712768, calculated from values for 2000, 1992, 1986, 1980, and 1973 on p. 6 of “...Land Value Predictions” document (I used an unweighted average; since the samples are not evenly spaced, would a weighted average be more appropiate?)

Forest-use predicted values

The expression for for\_val has 7 independent variables:

acres attribute AREA, converted from m2 to acres

slope new attribute SLOPE\_DEG, also needed for at least one other related model

elev attribute ELEV

riv\_feet new attribute STREAM\_LEN, converted from m to ft, from ?

PNI IDU.dbf does not currently distinguish between industrial and non-industrial private owners

ugbdist new attribute D\_UGB

citydist new attribute D\_CITY20K

county\_group attribute from attribute COUNTYID

imp = 47.81576, from p. 6 of “...Land Value Predictions” document

mean\_imp = 25.6702726, calculated from values for 2000, 1992, 1986, 1980, and 1973 on p. 6 of “...Land Value Predictions” document (I used an unweighted average; since the samples are not evenly spaced, would a weighted average be more appropiate?)

Example WW2100AP XML file

<envision> <ww2100>

<Coldstart ... </Coldstart>

<fish ... </fish>

<carbon ... </carbon>

<agtrans ... </agtrans>

<urbanwater ... </urbanwater>

<DGVMvegtypeData ... </DGVMvegtypeData>

<irrigation\_choice ... </irrigation\_choice>

<land-useTransitions in\_use=1 interval=’5’ >

<developed-use>

<coefficient symbol='beta0' value='10.80125' description='constant' />

<coefficient symbol='beta1' value='0.3640036’ description='UGB' />

<coefficient symbol='beta2' value='-0.5582139’ description='acres' />

<coefficient symbol='beta3' value='0.1050732’ description='pop\_den' />

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<coefficient symbol='beta6' value='0.0010084’ description='imp' />

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<coefficient symbol='beta8' value='0.000577’ description='citydist\_sq' />

<coefficient symbol='beta9' value='0.1125477’ description='Benton\_group' />

<coefficient symbol='beta10' value='-0.2621235’ description='Lane\_group' />

<coefficient symbol='beta11' value='0.2960158’ description='Washington\_group' />

<coefficient symbol=‘Correction\_factor’ value=‘1.035396’ />

<parameter symbol=‘imp’ value=‘93.92385’ ‘year 2000 developed-use ave improvement value’ />

</developed-use>

<agricultural-use>

<coefficient symbol='beta0' value='6.6813523' description='constant' />

<coefficient symbol='beta1' value='-0.0074373’ description='acres' />

<coefficient symbol='beta2' value='-0.0103311’ description='slope' />

<coefficient symbol='beta3' value='-0.028802’ description='citydist' />

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<coefficient symbol='beta5' value='-0.0316043’ description='Benton\_group' />

<coefficient symbol='beta6' value='-0.2965407’ description='Lane\_group' />

<coefficient symbol='beta7' value='-1.207552’ description='Washington\_group' />

<coefficient symbol='beta8' value='0.0012032’ description='imp' />

<coefficient symbol='beta9' value='0.0019667’ description='farm\_rent' />

<coefficient symbol='beta10' value='0.000824’ description='mean\_imp' />

<coefficient symbol=‘Correction\_factor’ value=‘1.103243’ />

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<parameter symbol=‘mean\_imp’ value=‘38.712768’ ‘mean agricultural-use improvement value’ />

</agricultural-use>

<forest-use>

<coefficient symbol='beta0' value=‘5.9666691' description='constant' />

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<coefficient symbol='beta2' value='-0.0493888’ description='slope' />

<coefficient symbol='beta3' value='-0.0010049’ description='elev' />

<coefficient symbol='beta4' value='-0.0000845’ description='riv\_feet' />

<coefficient symbol='beta5' value='0.2043399’ description='PNI' />

<coefficient symbol='beta6' value='0.0248954’ description='ugbdist' />

<coefficient symbol='beta7' value='-0.1148065’ description='citydist' />

<coefficient symbol='beta8' value='0.0018441’ description='citydist\_sq' />

<coefficient symbol='beta9' value='-0.9610304’ description='Benton\_group' />

<coefficient symbol='beta10' value='-0.3309582’ description='Lane\_group />

<coefficient symbol='beta11' value='-1.253873’ description='Washington\_group' />

<coefficient symbol='beta12' value='0.00032253’ description='imp' />

<coefficient symbol='beta13’ value='0.0059643’ description='mean\_imp' />

<coefficient symbol=‘Correction\_factor’ value=‘1.226005’ />

<parameter symbol=‘imp’ value=‘47.81576’ ‘year 2000 forest-use ave improvement value’ />

<parameter symbol=‘mean\_imp’ value=‘25.6702726’ ‘mean forest-use improvement value’ />

</forest-use>

<transitions >

<coefficient name=‘selfR’ value=’0.00489’ description=‘use w/ ARa and FRf’ />

<coefficient name=‘crossR’ value=‘0.00242’ offset\_value=’-7.799 description=‘use w/ FRa and ARf’ />

<coefficient name=’DR’ value=‘0.00013’ offset\_value=’-4.788’ />

<transition from\_use=’ag’ >

<to to\_use=’ag’ >

<parameter name=‘max’ value=‘200’ />

<coefficient name=‘scale\_factor’ value=‘0.05’ description=‘coef of ag\_val’ />

</to>

<to to\_use=‘forest’ >

<parameter name=‘max’ value=‘2000’ />

<coefficient name=‘scale\_factor’ value=‘1.6’ description=‘coef of for\_val/>

</to>

<to to\_use=‘developed’ >

<parameter name=‘max’ value=‘75000’ />

<coefficient name=‘scale\_factor’ value=‘1.0’ description=‘coef of dev\_val/>

</to>

</transition>

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<to to\_use=’ag’ >

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</to>

<to to\_use=‘forest’ >

<parameter name=‘max’ value=‘200’ />

<coefficient name=‘scale\_factor’ value=‘0.7’ description=‘coef of for\_val/>

</to>

<to to\_use=‘developed’ >

<parameter name=‘max’ value=‘75000’ />

<coefficient name=‘scale\_factor’ value=‘1.0’ description=‘coef of dev\_val/>

</to>

</transition>

</transitions>

</land-useTransitions>

</ww2100> </envision>

Missing information

- data layer for new IDU attribute D\_CITY20K, the Euclidean distance from the IDU to the city center of the nearest city in the list of cities on p. 6 of the “...Land Value Predictions” document

- I presume “Euclidean” is used here to emphasize distance measured as the crow flies as opposed to distance on roads. Is that correct?

- data layer for new IDU attribute SLOPE\_DEG, also needed for the crop choice model

- mean\_imp: I used an unweighted average; since the samples are not evenly spaced, would a weighted average be more appropiate?

- data layer for new attribute STREAM\_LEN, the “footage of rivers and streams running through IDU”

- data layer for a new attribute or a new value of the OWNER attribute, to distinguish industrial owners from non-industrial owners, which is neededfor the forest land value calculation

Appendix H. Urban water demand model

Urban and Residential Water Demand Model on Envision

File name: WW2100\_Models\_UrbanWaterDemand.doc

Bill Jaeger and Dave Conklin Date: July 6, 2013, rev. 8/28 REV 9/13, Revised Jan 31, 2014, Revisions recombined 2/28/2014. Revised again on 5/15/14 by Dave Conklin. Revised by Dan Bigelow on 08/15/14.

This model predicts demand for water in populated areas (excluding irrigation water demand). This includes separate versions for a) large cities, b) other cities, c) rural residential areas (any IDU where people live and have a water right). The quantity of water demanded depends on a range of independent variables including population, income, and price. In the case of rural residential pumping cost from groundwater proxies for price.

I. Four main cities

This model predicts daily urban water demand for the four main cities (Portland Metro, Salem, Corvallis, and Eugene-Springfield). Demand has two components, residential and non-residential.

Step 1:

Residential:

ln(QRAvg) = -(2.931236 + 0.610912\**IBR*) – (0.6\*ln(*p*)) +(ln(*Pop*)) + ((0.13 + 0.05\**IBR*)\*ln(*I*))

– (0.048\*ln(*D*))

*QRt* = (1-0.2(ETtG/ET0G)(Cos(2πd/365)))\**exp(ln(QRAvg))* [units are in ccf/day]

Non-residential:

*ln(QNRAvg)* = - 2.727616 – (0.6\*ln(*p*)) + (0.11\*ln(*Ind.I*)) + (0.04\*ln(*Comm.I*)) *+* (0.85\*ln(*Pop*))

*QNRt* = *exp(ln(QNRAvg)),*

where:

QR and QNR = sum to the total daily water use for the entire city in hundreds of cubic feet (ccf),

p = price in $/ccf,

Pop = city population,

D = density (persons per mile2),

I = median household income,

IBR = 1 if city has an Increasing Block Rate pricing structure, = 0 otherwise,

Ind. I = total city industrial (manufacturing) income in thousands of $, and

Comm. I = total city commercial income in thousands of $.

Step 2:

Residential demand is adjusted above for seasonality by (1-.2(ETtG/ET0G))(Cos(2πd/365)) above, where:

d is the day of the year (Jan.1 = 1, etc.),

ETtG and ET0G represent the evapotranspiration for urban lawn grass in year t and year 0, respectively, and t is the year (0 = initial year).

Baseline prices for the four main cities are:

Residential:

Portland (all of metro area): $2.44/ccf, Salem: $2.04/ccf, Corvallis: $1.93/ccf; Eugene-Springfield: $1.25/ccf.

Non-residential:

Portland (all of metro area): $2.44/ccf, Salem: $1.50/ccf, Corvallis: $2.11/ccf; Eugene-Springfield: $1.48/ccf.

IBR = 1 for Corvallis, Eugene-Springfield; IBR = 0 for Portland, Salem. Use IBR = 0 for other urban areas.

Baseline (initial) manufacturing income (x 1000 $):

Portland: 9,851,720; Salem: 651,857; Corvallis: 461,476; Eugene-Springfield: 723,165.

Baseline (initial) commercial income (x 1000 $):

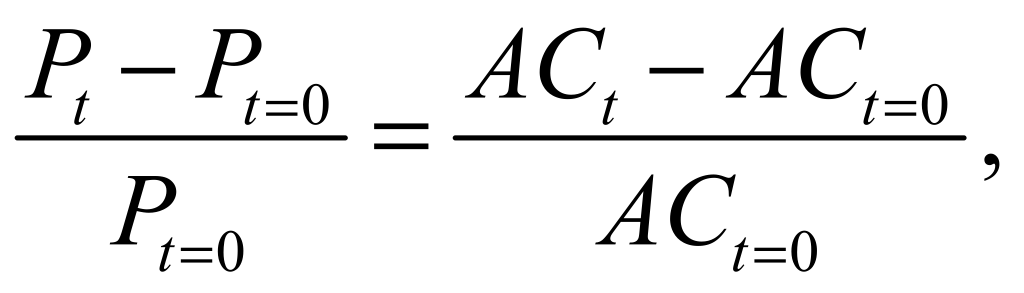
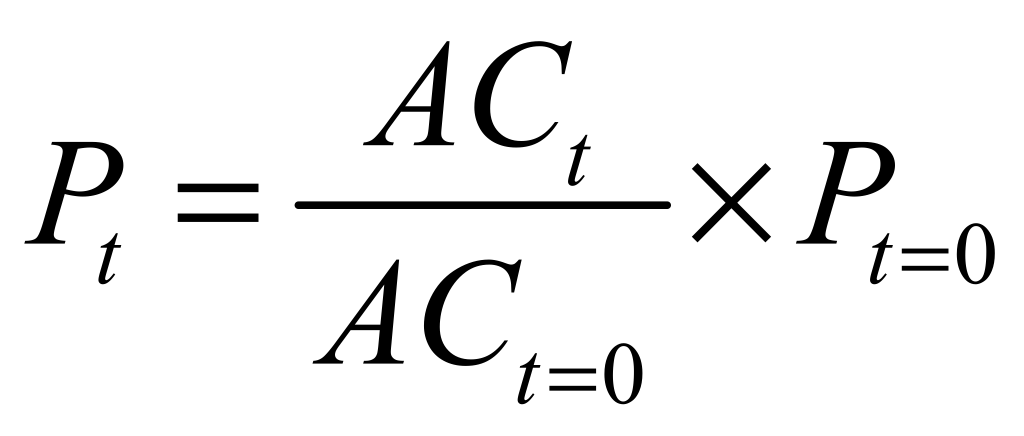
Portland: 58,292,148; Salem: 7,350,692; Corvallis: 1,598,343; Eugene-Springfield: 6,565,399.

Step 3:

Prices will change over time as a function of average current cost (based on current expenditures), which is a function of population, and water cooling costs if required. These relationships were estimated based on national data (EPA 2009).

ACt = (0.748/1000)\*exp{9.93 – 0.355 ln Pop(t) + 0.030(ln Pop(t))2 – 0.001(ln Pop(t))3} + COOL

We assume that prices will increase at the same rate as average cost:

then 

COOL is the cost to cool water that is returned instream when required to meet instream temperature requirements.

COOL = 0.3\*∆T\*(QC)/(Q)

Where ΔT is the decrease in temperature (degree F) required for the centralized return flow of QC. The total demand Q is the amount delivered to all customers in the municipality. Return flows will be a fraction of total water consumed. The cost 0.30/degree/ccf is estimated for chillers by OACWA (2000).

II. Other Cities

Demand for other cities will also be a function of population, income, and price ($/ccf). They will not have separate non-residential demand functions, nor will they use IRB pricing. Prices will be based on the water delivery average cost function, which declines with rising population.

Step 1:

ACt =(0.748/1000)\*exp{9.93 – 0.355 ln Pop(t) + 0.030(ln Pop(t))2 – 0.001(ln Pop(t))3} + COOL

Step 2:

Demand is based on assuming price equals AC from relationship above, so that

ln(QRt) = - 2.16432007 – (0.6\*ln(pt)) + ln(Popt) + (0.13\*ln(It)) - (0.048\*ln(Dt))

and pt = ACt.

COOL is defined as indicated in section I.

Step 3:

Demand in step 2 is adjusted for seasonality as follows:

QRt = (1-0.2(ETtG/ET0G))(Cos(2πd/365)))exp(ln(QRt*)*)

Residential demand is adjusted above for seasonality by (1-.2(ETtG/ET0G))(Cos(2πd/365)) above, where:

d is the day of the year (Jan.1 = 1, etc.),

ETtG and ET0G represent the evapotranspiration for urban lawn grass in year t and year 0, respectively, and

t is the year (0 = initial year).

III. Rural residential

Step 1: ln(QRR)= -3.55 – (0.6\*ln(PC)) + ln(Pop) + (0.13\*Ln(I)) - (0.048\*ln(D)), where:

PC = “price” for water ($/ccf) (cost of pumping, $0.3/ccf),

Pop = the population of the rural residential IDU,

I = income per household ($/household), average for relevant county, and

D = density (people per sq. mi.) (assumed to be 768 per square mile in rural residential areas, or two acres per household).

Demand (QRR) is in ccf/day.

Demand in step 1 is adjusted for seasonality as follows:

QtRR = (1-0.2(ETtG/ET0G))(Cos(2πd/365)))exp(ln(QRR),)

where:

d is the day of the year (Jan.1 = 1, etc.),

ETtG and ET0G represent the evapotranspiration for urban lawn grass in year t and year 0, respectively, and

t is the year (0 = initial year)

IV. Average Cost – Long run (including capital costs)

The model that determines price, and demand, will also track the evolution of estimated long-run average cost (LRAC) ($/ccf) as a function of changing population (but holding other variables constant).

LRAC = (0.748/1000)\*exp{ 13.39 – 1.246\*(ln(pop)) + 0.117\*(ln(pop)) 2 – 0.004\*(ln(pop)) 3}

This will permit monitoring the differences between price and cost, inefficiencies due to underpricing, and financial shortfalls for municipal water providers.

V. Implementation of the Urban and Residential Water Demand model in Envision

The urban and residential water demand (UWD) model will be implemented as a subprocess of the WW2100AP autonomous process plugin, running at the beginning of each annual simulation timestep. Input parameters will be supplied in the XML file used by WW2100AP. Mean daily water demand figures calculated in each annual timestep by WW2100AP will be passed into the Flow module. The daily timestep loop within Flow will calculate seasonally-adjusted daily demand values from the mean daily values using these relationships:

for non-residential use in the 5 major cities

seasonally-adjusted daily Q = mean daily Q

and in all other cases

seasonally-adjusted daily Q = mean daily Q \* (1 - 0.02 \* (ETt/ET0)\* cos(2 pi \* Julian day/365))

where ETt/ET0 is the ratio of annual urban lawn grass evapotranspiration in year t to its value in year 0 of the simulation. As of version 7908 of Flow/DailyurbanWaterDemand.cpp on 5/14/14, no estimate of the time series of urban lawn grass ET has been implemented, and the ETt/ET0 ratio is simply taken as unity.

In Envision, the UWD model produces, as output from each yearly timestep of the simulation, mean daily water demand and the cost of water for each of

Portland metro area

Eugene-Springfield

Salem

Corvallis

all other cities

average for rural residential areas

and an estimate of long-run average cost (LRAC in $/ccf).

For each of the 4 named cities, the model produces four numbers per annual timestep: total city-wide residential demand, total city-wide non-residential demand, average cost, and long run average cost. Demand values are in ccf/day. Costs are in $/ccf.

For each of the smaller cities, the model produces three numbers per timestep: demand (Q) in ccf/day, which combines both residential and non-residential uses, average cost (AC) in $/ccf, and long run average cost (LRAC) in $/ccf.

Rural residential demand is expressed as a single number for each IDU, in units of ccf/day.

There are a variety of input data times series required for the UWD model.

Population

Urban growth boundaries extend beyond city limits, so city populations are generally smaller than the populations of their associated urban growth areas. However, for this model, each city's population is taken as the prescribed, exogenous population for the city's urban growth area, as used in the population growth model, but for the calendar year preceding the simulation year. The use of the preceding year's population figure is consistent with the convention that the population growth model produces population figures for the end of the simulation year. The population growth model runs after actor decisions, at the end of the annual simulation timestep, while the urban water model runs at the beginning of the annual simulation timestep, in order to provide input data for the Flow model's daily timestep calculations.

Population density

Population density is calculated in each timestep by dividing the prescribed population for the UGA by the sum of the AREA attributes for all the developed IDUs within the UGA. Note this is the adjusted population density used in the population growth model. As of 5/15/14, Dave Conklin and Dan Bigelow had each discovered one or more small UGAs (e.g. Idanha) in which there are no privately-owned developed IDUs, and hence the adjusted population density is undefined. As of version 7899, the water demand is set to zero in those UGAs.

Baseline water prices for the 4 large cities in $/ccf

For the 4 large cities, specified in the XML file as two figures (residential price and non-residential price) for each city.

Data related to cooling cost calculations for the major cities

Cooling cost is a function of how much cooling is required, which in turn requires knowledge of in-stream temperatures, the maximum temperature constraints, and the fraction of the city water demand represented by the centralized return flow. As of 8/28/13 and as far as we know, exogenous time series for those data values are not available, nor are they provided by other parts of the WW2100 simulation. Nevertheless, a mechanism for specifying cooling costs is provided similar to that used for specifying household income, i.e. a .csv file with one column for each major city and each county, and one row for each year. In the initial version of the cooling\_cost.csv file, cooling costs will be set to zero.

Here is the “urban\_water” block from version 7909 (5/14/14) of the WW2100AP.xml file, minus embedded comments:

<urban\_water id='52' test\_mode="0"

manufacturing\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/mfg\_income.csv"

commercial\_income\_file="/Envision/StudyAreas/WW2100/ARECmodels/comm\_income.csv"

cooling\_cost\_file="/Envision/StudyAreas/WW2100/ARECmodels/cooling\_cost.csv" >

<prices>

<price\_ccf area="Portland Metro" residential="2.44" non-residential="2.44" IBR="0"/>

<price\_ccf area="Salem-Keizer" residential="2.04" non-residential="1.50" IBR="0"/>

<price\_ccf area="Corvallis" residential="1.93" non-residential="2.11" IBR="1"/>

<price\_ccf area="Eugene-Springfield" residential="1.25" non-residential="1.48"

IBR="1"/>

</prices>

</urban\_water>

The format for the household income, manufacturing income, commercial income, and cooling cost data files is:

- comma-separated text (.csv), from Excel

- first row has column headings, e.g. "year, Benton, Clackamas, ..., Yamhill, Metro, Salem, Corvallis, Eugene-Springfield"

- succeeding rows have data for one year, e.g.

"1969, 41157, 58580, ..., 46627, 53253, ..."

Income data for the counties and the Portland Metro UGA, in the form of a spreadsheet file, "WW2100\_pop\_inc\_data.xlsx", was provided by Dan Bigelow on 7/11/13. With the exception of the Metro UGA, the income term in the equation for demand UGAs is interpreted as the average household income for the county where the city is located (or the area-weighted average of multiple counties where the UGA crosses county lines). Cooling costs will be set to zero in the initial version of the cooling cost data file. Note that the format for the cooling cost file, like that for the household income file, implies that the cooling cost value for the smaller cities is taken as the average cooling cost for the county in which the city is located.

**Updates to model**

08/2014: Price path adjusted in accordance with Bill Jaeger’s task #16

1. We now want urban water prices to follow a path that includes a “ramp up” in prices over the first 15 years of the scenario. In the As-Built document, we have baseline prices for the four main cities (residential and non-residential). Currently these prices may adjust over time if average cost changes due to a) population growth or b) non-zero “COOL” values. Prices will change in proportion to the changes in average cost.

Now, we want all prices to increase at a rate of 1.5% per year for the first 15 years. This is a compounding increase (each year’s increase is 1.5% higher than the previous year’s price). The total increase in price will be 25% over the 15 year period. Then, starting in year 16 (2026), prices will change only as a result in further changes (from year 2026 onward) in the average cost function. To be clear: if average cost declines by 1% in year 2027 relative to 2026 in city Z, then the price should decline by 1% in year 2027 relative to year 2026.

 for years 2 to 15.

We assume that prices will increase at the same rate as average cost starting in year 16:

 for t ≥ 16

For “other cities” make the equivalent change: a) start with prices equal to average cost (as we now do), b) increase prices 1.5% each year for 15 years, c) starting in year 16, only change price if average cost changes.

References

Environmental Protection Agency (EPA), 2009. 2006 Community Water System Survey.

Oregon Association of Clean Water Agencies, 2000. Temperature Management Plan: Guidance Manual. [www.oracwa.org/pdf/temperature-mgmt-plan.pdf](http://www.oracwa.org/pdf/temperature-mgmt-plan.pdf)

Appendix I.

Coding Instructions for land-use transitions, zoning, and UGB expansions in WW2100

Andrew Plantinga

Land-use transitions

The first section of this document describes how land-use transitions will happen in the reference scenario developed for WW2100. This component of the model (as well as the components related to zoning and UGB expansions) is concerned only with privately-owned land in 10 counties in the Willamette Basin (Benton, Clackamas, Columbia, Lane, Linn, Marion, Multnomah, Polk, Washington, Yamhill). Further, it only considers land in three uses (or land covers, as defined by the LULC A layer): agriculture, forest, and developed. All other land (in public uses, in counties other than the 10 indicated above, or in uses other than agriculture, forest, or developed) is assumed to remain in the same use.

With three uses, there are a total of nine possible transitions (counting transitions in which land does not change use; e.g., forest-to-forest). For our component, this number is reduced to six because land that is in developed use can be assumed to remain in that use indefinitely. Thus, we are concerned with the following six transitions:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | Ending uses | | |
| agriculture | forest | Developed |
| Starting uses | Agriculture | Paa | Paf | Pad |
| Forest | Pfa | Pff | Pfd |

In particular, we model the probability that each transition takes place, where Pjk in the above matrix indicates the probability that land moves from use j to use k (e.g., Paf is the probability that land moves from j=agriculture to k=forest). Because land has to end up in one of the three categories, it follows that Paa+Paf+Pad=1 and Pfa+Pff+Pfd=1.

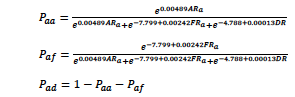
The base year (2006) land cover map indicates the land cover category for each IDU. For those IDUs that begin 2006 in agriculture or forest (and meet the above criteria related to ownership and counties), we define the six probabilities indicated above as logistic functions of IDU attributes. Formulas given below define transition probabilities for a five-year period (e.g., 2006 to 2011, 2011 to 2016). Calculation of these transition probabilities requires three steps. First, for each IDU we calculate the economic returns to each of the three land uses (dev\_val, ag\_val, and for\_val). The equations used to compute each of these values is given in a separate document (Calculating economic returns for each IDU.pdf).[[9]](#footnote-9) Note that some of the IDU attributes do not change over time (e.g., slope) but others do change (e.g., population and income of nearest city). Second, the computed economic returns (dev\_val, ag\_val, and for\_val) are scaled using formulae given below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Economic return to: | | |
|  |  | agriculture | forest | developed |
| Starting use | agriculture | min(max(0,ag\_val\*0.05),200) | min(max(0,for\_val\*1.6),2000) | min(max(0,dev\_val),75000) |
| forest | min(max(0,ag\_val\*0.01),2000) | min(max(0,for\_val\*0.7),200) | min(max(0,dev\_val),75000) |

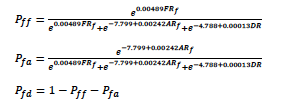
For example, if an IDU begins in forest, then the economic return to agriculture on that IDU is found by first computing ag\_val, multiplying ag\_value by 0.01, and then (if necessary) constraining the result to lie between 0 and 2000. I will refer to the scaled/constrained values of the economic returns as ARa, FRa, and DRa when the starting use is agriculture and ARf, FRf, and DRf when the starting use is forest. Because DRa=DRf, I will simply refer to this value as DR.

Once the values of ARa, FRa, and DR or ARf, FRf, and DR are determined for each IDU, the third step is to plug them into formulas that determine the five-year transition probabilities.

Specifically, for IDUs starting in agriculture, the five-year transition probabilities are given by:



For parcels starting in forest, the five-year transition probabilities are given by:



We want to represent land-use change on a more frequent than every five years. In particular, we want to allow for annual changes in land use. To this end, the five-year probabilities can be converted to equivalent annual probabilities using the following formula: if Pjk is the five-year transition probability, then the corresponding annual transition probability (APjk) is given by:

APjk=1-(1-Pjk)0.2

When Envision is run, the annual probabilities should be used for a five-year period before they are updated.

Given sets of values of APjk for each IDU, the final step is to determine whether or not land-use changes actually occur on an IDU. For this, we will use a random number generator. Suppose that a given IDU is currently in agriculture and has an 80% probability of remaining in agriculture (i.e., APaa=0.80), a 10% probability of switching to forest (APaf=0.10) and a 10% probability of switching to developed use (APad=0.10). Then, if one draws a random variable r from a uniform distribution defined on the unit interval, the IDU would remain in agriculture if 0.8>r≥0, change to forest if 0.9>r≥0.8, and change to developed use if 1.0≥r≥0.9. This procedure is repeated for each IDU (in particular, a new random variable is drawn for each IDU). The result is that a new landscape is produced.

To summarize, the steps are:

1) Identify the starting use for each IDU

2) Compute the economic returns for each IDU

3) Scale/constrain the economic returns from step 2 using the formulae corresponding to the starting use

4) Plug the new economic returns from step 3 into the formulae for transition probabilities corresponding to the starting use

5) Convert the 5-year transition probability into an annual transition probability

6) Draw random variables for each IDU and determine the new land use for that IDU

7) If less than five years has elapsed since the last five-year probabilities were computed, continue with steps 1 and 6.

8) If five years has elapsed since the last five-year probabilities were computed, continue with steps 1 through 6.

Zoning and UGB expansions

For the reference scenario, we will assume that land outside of UGBs can move between undeveloped uses (i.e., ag-to-forest and forest-to-ag transitions are allowed) but changes to developed use are not allowed. To account for this restriction on development, the transition probabilities need to be adjusted. For IDUs outside of UGBs, the probability associated with the transition to developed use should be added to the probability associated with the land remaining in the same use. Thus, if the initial use is agriculture, Paa(new)=Paa(old)+Pad. If the initial use is forest, Pff(new)=Pff(old)+Pfd. Note that the restriction on development also applies to areas zoned as rural residential (which are outside of UGBs) since only a small portion of the lot is allowed to be developed.

For IDUs inside of UGBs, all of the transitions are allowed. Given the irreversibility of development, it follows that, over time, the share of developed land within each UGB will increase. To mimic the land-use planning process, we allow for UGBs to expand once the developed share becomes sufficiently large. The developed share is defined as the ratio of the area of private land within a UGB that is developed to the area of private land within a UGB that is developable. Developable land includes all land that is in developed, agriculture, other vegetation, and forest categories. It excludes land in the barren, wetlands, and water/snow/ice categories. As long as the developed share is below 80%, the existing UGB remains as it is. However, once the 80% threshold is exceeded, a UGB expansion is triggered. For simplicity, we’ll assume that the need for a UGB expansion is evaluated every five years, coinciding with the updating of the five-year transition probabilities.

A UGB expansion involves adding new IDUs to the existing UGB area until the 80% threshold is no longer exceeded. Which IDUs to add is determined by the following criteria:

1) Only select IDUs that are privately-owned and developable (i.e., in developed, agriculture, other vegetation, or forest categories).

2) Do not select IDUs that are already inside another UGB.

3) Select IDUs in order of least distance between the centroid of the IDU and the city center of the UGB area.

4) Only select IDUs that are adjacent to the existing (or expanded) UGB area.

5) Do not select IDUs that are zoned for agriculture, forest, or agriculture/forest resource use unless there are no other IDUs that satisfy criteria 1, 2, and 4. In this case, select IDUs that are zoned for agriculture, forest, or agriculture/forest resource use using criteria 3 during the current expansion event. Agriculture, forest, and agriculture/forest zones are defined by the “GENERAL\_ZONING” field in the DLCD statewide zoning map.

These criteria do not apply to expansions in the Portland metro UGB. In this case, the regional planning authority (Metro) has designated areas called urban reserves where future expansions, out until the year 2060, will take place. Metro has also designated rural reserves, where development will be prohibited until 2060. For expansions in the Portland metro UGB:

A) Until the year 2060,

1) Only select areas within designated urban reserves

2) Select IDUs in order of least distance between the centroid of the IDU and the city center of the UGB area.

3) Only select IDUs that are adjacent to the existing (or expanded) UGB area.

4) If the urban reserves are exhausted prior to 2060, then continue with criteria 1-5. However, inclusion within the UGB should be limited to IDUs that are not in a rural reserve.

B) After the year 2060,

1) Treat Metro like all other UGBs in the study area, following criteria 1-5 above for UGB expansions.

Appendix J. Calculating economic returns for each IDU

Documentation for WW2100 land value predictions

07/01/13

**General procedure**

For each of the three land uses, the property values were estimated using a semi-log specification, meaning that the dependent variable is in natural-log form and the independent variables are not transformed. To arrive at the final predicted values for each IDU, three steps must be taken:

1. Predict the natural log of the property value using the equations given below.
2. Exponentiate the predicted value.
3. Correct for non-linearity by multiplying by the relevant correction factor.

Note that each respective IDU will have three predicted values: (1) developed-use, (2) forest-use, and (3) agricultural-use.

**Developed-use predicted values**

**Equation:**

**Correction factor:** 1.035 (i.e. true value equals )

**Variable descriptions/parameter values for developed-use value predictions**



**Agricultural-use predicted values**

**Equation**

****

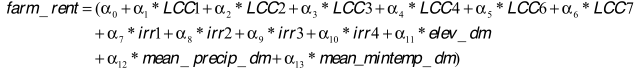
**Correction factor:** 1.167 (i.e. true value equals )

**Variable descriptions/parameter values for agricultural-use value predictions**



**Farm rent variables**

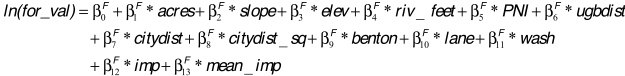
The agricultural-use equation contains a variable that measures per-acre farm rental values. That variable is computed as follows:





**Forest-use predicted values**

**Equation**



**Correction factor:** 1.226 (i.e. true value equals )

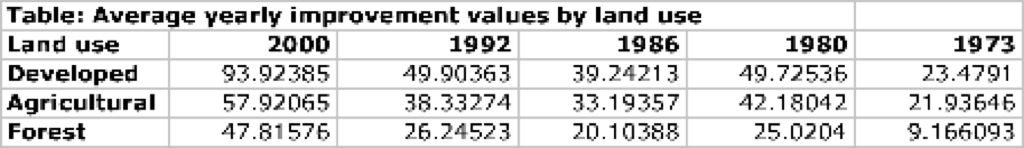
**Variable descriptions/parameter values for forest-use value predictions**



**Appendix tables**







**Appendix K:** Alternative scenarios involving the economics models.

* + - 1. **Alternative population scenario (AltPop-MIROC)**

The alternative population scenario has been implemented in full as of 08/13/14. This scenario uses the MIROC climate projections. The alternative population scenario features an augmented growth path for the individual, UGA-specific population projections. Specifically, population growth in each time step is doubled relative to the reference case. In terms of implementation, this scenario entailed making changes to the following items in the Envision repository: wv\_Scenarios.xml, WW2100AP.xml, EconModels.cpp, WW2100AP.cpp, and WW2100AP.h. A .csv file containing the alternative population projections was supplied by Dan Bigelow and placed in the newly created ‘Pop\_UGBx2’ subfolder. The reference case population projections are now contained in their own subfolder named ‘Pop\_Ref’.

* + - 1. **Alternative UGA expansion scenario (AltUGAThresh-MIROC)**

The alternative UGA expansion scenario has been implemented in full as of 08/13/14. This scenario uses the MIROC climate projections. The alternative UGA expansion scenario features an augmented UGA expansion threshold % for each UGA in the study area. Specifically, each UGA-specific expansion threshold is set to 70%, rather than 80% as in the reference case (72% in the case of Eugene-Springfield). In terms of implementation, this scenario entailed making changes to the following items in the Envision repository: wv\_Scenarios.xml, WW2100AP.xml, EconModels.cpp, WW2100AP.cpp, and WW2100AP.h. A .csv file containing the UGA-specific expansion threshold percentages was supplied by Dan Bigelow. That file is named ‘UGA\_threshold’ and can be found in the ‘ARECModels’ subfolder.

1. Note that this only pertains to the UGBs representing cities within the WRB that have a population greater than 20,000 as of 2010. Population will be added to all UGBs in the WRB, but only those representing the 20,000+ cities will be allowed to expand in the reference scenario. [↑](#footnote-ref-1)
2. See newer XML example in As-built note 2. [↑](#footnote-ref-2)
3. originally this was greater than or equal to - see as-built note #4 [↑](#footnote-ref-3)
4. currently assumed to be 2010 [↑](#footnote-ref-4)
5. See as-built note #10. [↑](#footnote-ref-5)
6. See as-built note #6 for a change to this. [↑](#footnote-ref-6)
7. See as-built note #7. [↑](#footnote-ref-7)
8. See as-built note #8 for a change. [↑](#footnote-ref-8)
9. One of key variables for determining economic returns to developed use is population density. The population of each city (as defined by areas within UGBs) is determined exogenously. Population density is computed as the ratio of population to the area of private land within the UGB that is in developed use (more discussion is provided below). [↑](#footnote-ref-9)