Appendix F
Supporting Information on Analysis of Supply and Demand

Statewide Water Supply Initiative

Appendix F: Supporting Information on Analysis of Supply and Demand

CDM

Arkansas Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Subbasin	County	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Upper Arkansas	Lake	3,917										
	Chaffee	24,406										
	Fremont	19,272										
	Teller	19,272										
	Custer	19,633										
Subtotal		**86,500**	**1,000**	**2,000**	**1,000**	**3,000**	**0**	**0**	**0**	**0**	**(2,000)**	**(5,000)**
Urban Counties	El Paso	15,010										
	Pueblo	35,638										
Subtotal		**50,648**	**1,000**	**2,000**	**10,000**	**15,000**	**0**	**0**	**0**	**0**	**(11,000)**	**(17,000)**
Lower Arkansas	Crowley	21,647										
	Otero	63,001										
	Bent	62,709										
	Prowers	79,929										
Subtotal		**227,286**	**0**	**0**	**5,000**	**40,000**	**4,000**	**8,000**	**0**	**0**	**(9,000)**	**(48,000)**
Eastern Plains	Elbert	Non-trib GW										
	Lincoln	Non-trib GW										
	Baca	Non-trib GW										
	Kiowa	Non-trib GW										
	Cheyenne	Non-trib GW										
Subtotal		**0**										
Southwestern Arkansas	Huerfano	16,208										
	Las Animas	24,020										
Subtotal		**40,228**	**250**	**500**	**500**	**1,000**	**0**	**0**	**0**	**0**	**(750)**	**(1,500)**
TOTAL		**404,662**	**2,250**	**4,500**	**16,500**	**59,000**	**4,000**	**8,000**	**0**	**0**	**(22,750)**	**(71,500)**

Colorado Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
36	Blue River	7,642	100	200	0	0	0	0			(100)	(200)
37	Eagle River	7,314	1,000	2,000	0	0	0	0			(1,000)	(2,000)
38	Roaring Fork River	22,119	2,000	4,000	0	0	0	0			(2,000)	(4,000)
39	Elk / Rifle / Parachute Creeks	16,272	500	1,000	0	0	0	0			(500)	(1,000)
45	Divide Creek	32,065	500	1,000	0	0	0	0			(500)	(1,000)
50	Troublesome / Muddy Creeks	17,566	100	200	0	0	0	0			(100)	(200)
51	Fraser / Colorado Rivers	22,378	500	1,000	200	700	0	0			(700)	(1,700)
52	Piney River	3,061	0	100	0	0	0	0			-	(100)
53	Rock / Derby / Sweetwater / Deep Creeks	13,875	0	0	0	0	0	0			-	-
70	Roan Creek	6,309	0	0	0	0					-	-
72	Plateau Creek / Colorado River	89,144	2,000	4,000	1,000	2,000			0	0	(3,000)	(6,000)
TOTAL		**237,745**	**6,700**	**13,500**	**1,200**	**2,700**	**0**	**0**	**0**	**0**	**(7,900)**	**(16,200)**

Dolores/San Juan/San Miguel Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
29	San Juan River	11,504	200	400	0	0	0	0	0	0	(400)	(200)
30	Animas River	26,056	200	400	0	0	0	0	0	0	(400)	(200)
31	Los Pinos River	40,630	300	600	0	0	0	0	0	0	(600)	(300)
32	McElmo Creek	79,729	100	200	0	0	0	0	0	0	(200)	(100)
33	La Plata River	19,527	100	200	0	0	0	0	2,000	4,000	1,800	3,900
34	Mancos River	10,518	200	400	0	0	0	0	0	0	(400)	(200)
60	San Miguel River	40,229	200	400	100	200	0	0	0	0	(600)	(300)
61	Dolores River	2,899	0	0	0	0	0	0	0	0	-	-
63	Dolores River	2,443	0	0	0	0	0	0	0	0	-	-
69	Disappointment Creek	1,216	0	0	0	0	0	0	0	0	-	-
71	Dolores River	6,232	0	100	0	0	0	0	0	0	(100)	-
73	Little Dolores River	2,015	0	0	0	0	0	0	0	0	-	-
77	Navajo River	3,273	0	0	0	0	0	0	0	0	-	-
78	Piedra River	8,228	200	400	0	0	0	0	0	0	(400)	(200)
TOTAL		**254,499**	**1,500**	**3,100**	**100**	**200**	**0**	**0**	**2,000**	**4,000**	**(1,300)**	**2,400**

Gunnison Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
28	Tomichi Creek	28,053	200	700	0	100	0	0	0	0	(200)	(800)
40	North Fork Gunnison / Gunnison Rivers	76,146	200	700	200	700	0	0	0	0	(400)	(1,400)
41	Uncompahgre River	84,737	1,000	3,000			0	0	0	0	(1,000)	(3,000)
42	Gunnison River	4,565	100	400	100	400	0	0	0	0	(200)	(800)
59	Taylor / East / Gunnison Rivers	31,606	500	3,000	0	200	0	0	0	0	(500)	(3,200)
62	Cebolla Creek / Lake Fork Gunnison River / Gunnison River	22,825	0	0	0		0	0	0	0	-	-
68	Uncompahgre River	15,622	200	700	0	100	0	0			(200)	(800)
TOTAL		**263,554**	**2,200**	**8,500**	**300**	**1,500**	**0**	**0**	**0**	**0**	**(2,500)**	**(10,000)**

North Platte Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
47	North Platte	112,624	0	0	0	0	0	0	0	0	0	0
48	Laramie & Sand Crk	3,085	0	0	0	0	0	0	0	0	0	0
76	Laramie & Sand Crk	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**115,709**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Rio Grande Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
20	Rio Grande River	350,822	100	200	100	200	22,350	40,700	0	0	(22,550)	(41,100)
21	Alamosa River	55,999	0	0	100	200	8,000	12,000	0	0	(8,100)	(12,200)
22	Conejos River	86,247	0	0	100	200	0	0	0	0	(100)	(200)
24	Culebra Creek	27,232	0	0	0	0	0	0	0	0	-	-
25	San Luis Creek	33,889	0	0	100	200	8,000	12,000	0	0	(8,100)	(12,200)
26	Saguache Creek	29,427	0	0	100	200	8,000	12,000	0	0	(8,100)	(12,200)
27	Camero / La Grita Creek	21,105	0	0	0	0	8,000	12,000	0	0	(8,000)	(12,000)
35	Trinchera Creek	27,959	0	0	50	100	5,000	10,000	0	0	(5,050)	(10,100)
TOTAL		**632,680**	**100**	**200**	**550**	**1,100**	**59,350**	**98,700**	**0**	**0**	**(60,000)**	**(100,000)**

South Platte Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Subbasin	County	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Denver Metro	Adams	40,925										
	Denver	2,109										
	Jefferson	818										
Subtotal		**43,853**	**5,000**	**10,000**	**10,000**	**20,000**	**0**	**0**	**0**	**0**	**(15,000)**	**(30,000)**
South Metro	Arapahoe	7,223										
	Douglas	3,125										
	Elbert	7,193										
	El Paso	172										
Subtotal		**17,713**	**2,000**	**4,000**	**3,000**	**5,000**	**0**	**0**	**0**	**0**	**(5,000)**	**(9,000)**
Upper Mountain	Clear Creek											
	Gilpin											
	Park	8,183										
	Teller											
Subtotal		**8,183**	**1,000**	**2,000**	**2,000**	**4,000**	**0**	**0**	**0**	**0**	**(3,000)**	**(6,000)**
High Plains	Cheyenne	Non-trib GW										
	Kit Carson	Non-trib GW										
	Lincoln	Non-trib GW										
	Phillips	Non-trib GW										
	Yuma	Non-trib GW										
Subtotal												
Northern	Boulder	43,339										
	Broomfield	4,395										
	Larimer	101,727										
	Weld	483,461										
Subtotal		**632,923**	**30,000**	**40,000**	**20,000**	**40,000**	**5,000**	**10,000**	**0**	**0**	**(55,000)**	**(90,000)**
Lower Platte	Logan	112,164										
	Morgan	164,867										
	Sedgwick	28,687										
	Washington	18,986										
Subtotal		**324,703**	**500**	**1,000**	**5,000**	**10,000**	**50,000**	**80,000**	**0**	**0**	**(55,500)**	**(91,000)**
TOTAL		**1,027,374**	**38,000**	**57,000**	**40,000**	**79,000**	**55,000**	**90,000**	**0**	**0**	**(133,000)**	**(226,000)**

Yampa/White/Green Basin - Estimate of Potential Changes in Agricultural Irrigated Acres 2000 - 2030

Water District	River/Stream	Estimate of Existing Irrigated Acres	Potential decrease in irrigated acres due to urbanization		Potential decrease in irrigated acres resulting from transfers		Potential decrease for other reasons		Potential increase in irrigated acres if additional supplies are developed		Total potential change of irrigated acres	
			Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
44	Williams Fork / Yampa River	30,200	0	100	0	0	0	0	0	11,000	(100)	11,000
54	Slater Creek / Little Snake River	14,371	0	0	0	0	0	0	0	11,000	-	11,000
55	Little Snake River	2,383	0	0	0	0	0	0	0	11,000	-	11,000
56	Green River	1,774			0	0	0	0	0	1,000	-	1,000
57	Yampa River	9,108	100	200	100	200	0	0	0	6,000	(400)	5,800
58	Elk / Yampa Rivers	31,917	1,000	2,000	0	0	0	0	0	0	(2,000)	(1,000)
Subtotal		**89,753**	**1,100**	**2,300**	**100**	**200**	**0**	**0**	**0**	**40,000**	**(2,500)**	**38,800**
43	White River	28,700	0	100	0	0	0	0	0	0	(100)	-
TOTAL		**118,453**	**1,100**	**2,400**	**100**	**200**	**0**	**0**	**0**	**40,000**	**(2,600)**	**38,800**

WatSIT (Water Supply Investigation Tool):
a water allocation screening model

1.) Overview:

WatSIT is a screening level water allocation model designed to provide quantitative comparisons of water supply alternatives with respect to yields, storage requirements, and return flows. It is intended to be used as an initial step in a water supply alternatives analysis for a basin, sub-basin, water district, or individual user. The model can operate at monthly or annual timesteps for up to 100 years of simulated hydrologic record. Any combination of up to four available generic project alternatives can be simulated: agricultural land transfer, reuse, consumptive use (non-ag) acquisition, and conservation. WatSIT predicts reservoir storage, or instream flow, and return flows as functions of baseline inflows, additional supply provided by project alternatives, and calculated demands. The model has proved to be particularly useful for quantifying firm yields associated with streamflow time series as functions of total reservoir storage.

The model is written in Visual Basic for Applications (VBA) and framed in a straight-forward and easy-to-use Excel-based interface. This structure makes the model well-suited for client use and supporting new business pursuits.

2.) Model Inputs and Outputs:

Model inputs and outputs are summarized in Table 2-1. Not all of the listed inputs are required for any single simulation run.

A snapshot of the "Main" input screen is shown in Figure 2.1. Through this screen, the user selects whether to run the model at monthly or annual timesteps and whether the direct source of water is a reservoir or a reach (i.e. where the water is ultimately drawn from). The simulation duration can be from 1 to 100 years.

Baseline inflows must be specified for each timestep for the full simulation duration. These baseline inflows represent "natural" or historical available flows without additional supply alternatives. For simulation durations greater than one year, monthly or annual baseline inflows are input on a separate sheet, which are automatically created when the user selects a "POR" (period of record) simulation rather than a single year simulation.

The user can also select up to four (4) generic project alternatives (in any combination) or none at all. The alternatives either provide "new" water to the system (ag transfer and non-ag acquisition) or reduce user demand on the water already available (conservation and reuse). Each come with their own set of inputs, organized in separate worksheets.

In the "Use" input sheet, the user must define the baseline gross total water usage of the water users at either monthly or annual timesteps. This parameter represents the actual

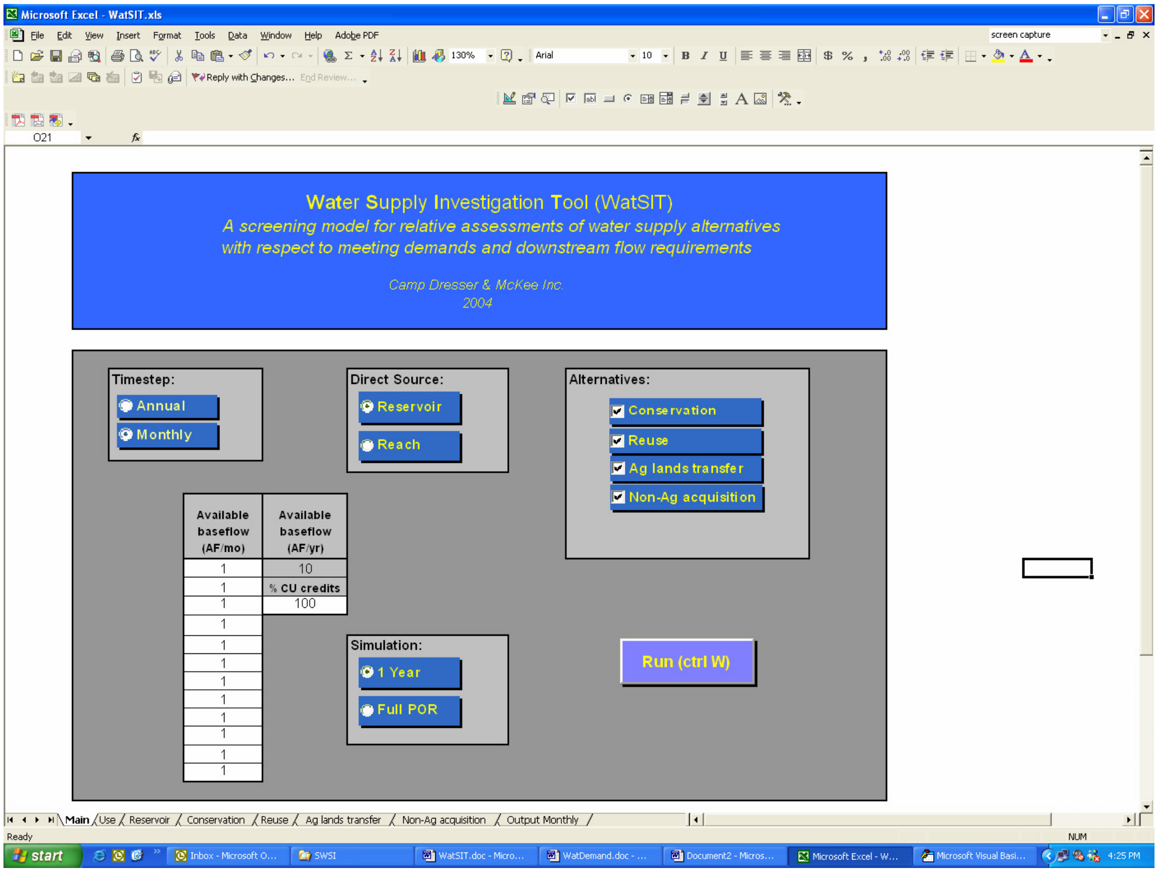

Figure 2.1
WatSIT Starting Input Screen

Table 2-1 **Summary of WatSIT Inputs and Outputs**		
parameter	*units*	*description*
Inputs:		
"Main"		
available baseflow (baseflow_annual or baseflow_monthly)	AF/Yr or AF/Mo	baseline currently available water (without alternatives)
% CU credits (baseflow_CU)	%	percent of baseline water that is available for consumptive use
"Use"		
baseline use (total_use_annual or total_use_monthly)	AF/Yr or AF/Mo	the baseline current water usage (without conservation, etc.)
% indoor use (percent_indoor_annual or percent_indoor_monthly)	%	the percent of baseline use that is indoor use
% CU indoor (percentCU_annual_in or	%	percent of indoor use that is consumptive

percentCU_monthly_out)		
% CU outdoor (percentCU_annual_out or percentCU_monthly_out)	%	percent of outdoor use that is consumptive
annual climate adjustment factor (climate_adjust)	unitless	factor that accounts for changes in annual outdoor use due to climate change
"Reservoir" (if selected)		
reservoir storage capacity (res_capacity)	AF	the maximum capacity of the reservoir (or system of reservoirs)
reservoir starting storage (res_vol_init)	AF	the initial reservoir volume (at start of simulation)
reservoir CU in starting storage (res_init_CU)	%	percent of starting volume in reservoir that is available for CU
minimum allowed volume (res_percent_min)	%	minimum allowable reservoir volume, expressed as a percentage of full capacity
reservoir volume : area table (res_vol, res_area)	AF vs. Ac	provides the relationship between reservoir volume and surface area in tabular form
average evaporation rate (evap_rate_annual or evap_rate_monthly)	inches / day or % volume	annual or monthly average evaporation rate for the reservoir
min. release (res_release_min_annual or res_release_min_monthly)	AF/Yr or AF/Mo	required reservoir minimum release (e.g. mandated to meet downstream requirements)
"Reach" (if selected)		
minimum instream flow (reach_min_annual or reach_min_monthly)	cfs	monthly or annual average minimum flow requirement for the source reach
reach losses (reach_losses)	AF/Yr	average annual natural loss from source reach (lost from system, not available for use)
"Conservation" (if selected)		
reduction in indoor usage (conservIn_reduct_annual or conservIn_reduct_monthly)	%	percent reduction in total indoor usage from conservation
reduction in outdoor usage (conservOut_reduct_annual or conservOut_reduct_monthly)	%	percent reduction in total outdoor usage from conservation
option for drought-only conservation	-	conservation is activated only if storage or flow levels are low
drought-only criteria (minimum storage volume or flow)	% (of capacity) or cfs	the hydrologic trigger that activates conservation when criteria is met
"Reuse" (if selected)		
recapture percentage (reuse_recap)	%	percent of available reusable water that is recaptured and reused, presumably for irrigation; generally <= 60 – 70%
return flows irrigation (returnFlow_irr)	%	percent of reuse water used for irrigation that gets returned
exchange percentage (reuse_exch)	%	percent of available reusable water that is reused via exchange

		<= 100%
return flows in & out (returnFlow_exch)	%	average percent of reuse water (via exchange) used indoor & outdoor that gets returned
"Ag lands transfer" (if selected)		
ag lands retired (ag_lands)	Ac	acres of agricultural lands that get dried up to provide water supply
irrigation efficiency (ag_effic)	%	amount of water consumed divided by amount diverted at farm headgate
ag net annual CU	AF/Ac	annual average consumptive use of ag lands
monthly distribution percentages	%	Breakdown of seasonal delivery of water from ag lands retirement
"Non-Ag acquisition" (if selected)		
water rights acquired (nonAg_transfer)	AF/Yr	non-ag water acquired as a supply alternative (e.g. from transbasin delivery)
Outputs:		
ending reservoir volume (res_vol)	AF	reservoir volume at end of timestep
reservoir overflow (res_overflow)	AF	reservoir overflow during timestep
reservoir release (res_release)	AF	amount of water released from reservoir during timestep
remaining reach flow (reach_flow)	cfs	instream flow (reach source) remaining at end of timestep
delivered water (demand_met)	AF	total external water delivered to M&I users during timestep
shortage (shortage)	AF	the difference of demand minus demand_met: the un-met gap
downstream return flow (net_returnFlow)	AF	the net amount of water that gets returned to the system downstream of M&I
reused water (reused_water)	AF	the total amount of water that gets reused (1st time reuse quantity)

water used, before conservation (thus "baseline"), and independent of reuse. As described in Section 3, reuse reduces *demand* but not usage. For zero reuse, demand equals usage. In this sheet, the user must also specify the percent consumptive use and the percent of the total use that is indoor for each timestep. Percent outdoor use is implied by the indoor percentage (100% - indoor). Monthly distributions of usage, based on a user-specified total usage, can also be automatically set according to pre-defined monthly percentages corresponding to typical M&I or agricultural use.

If the direct source of water is a reservoir, then the "Reservoir" sheet is created. The parameters in this sheet can either represent a single reservoir or an aggregation of reservoir storage. In this sheet, the physical characteristics of the reservoir, or reservoir system, are specified: capacity, initial storage (and the percent of this initial storage that is available for consumptive use), and area-volume relationship. The user can also specify minimum storage and release requirements associated with the reservoir. Release requirements can vary with month of the year (for monthly timestep simulations). Finally, annual or monthly evaporation rates (either as inches per day or percent volume) must be estimated and input here.

For a reach source, the only input requirements (if applicable) are minimum instream flow constraints (which can vary by month) and average annual reach loss. This latter parameter represents net losses of water from the reach not associated with meeting supply demands (e.g. seepage to underlying aquifers).

For each alternative selected, a new input sheet is displayed (named accordingly). For the conservation alternative, the input requirements are the percent reductions in indoor vs. outdoor usages (either by month or annual average). The user also has the option of implementing conservation only during low flow/storage periods. A check box is selected and the user must subsequently input either the minimum reservoir volume or the minimum reach flow that activates the conservation.

For the reuse alternative, the exchange reuse percentage (for multiple uses) and the recapture reuse percentage (for irrigation only) are both required inputs. These values represent the percentage of available water that is reused under the two types of programs, respectively. The combined percentage cannot exceed 100%. Water available for reuse, as detailed in Section 3, is the non-CU water for which there are consumptive use credits. The percent return flows associated with each reuse type are also required (i.e. the amount of water reused that gets returned).

For the ag lands transfer alternative, the user must specify the acres of lands to be retired, the net annual consumptive use associated with those acres, the irrigation efficiency of the farms, and monthly distribution percentages. The irrigation efficiency is the ratio of the farm consumptive use to the water supplied at the farm headgate. In other words, it represents the efficiency of the farmer's irrigation system (how much water is needed compared to how much is actually consumed by the crops). Monthly distribution percentages provide the monthly breakdown of delivered flow from the ag lands transfer. In other words, seasonal variation in the amount of water available from the transfer can be specified here.

For the non-ag water acquisition, the only input requirement is the total annual volume of water acquired.

Current model outputs (for each timestep) are: reservoir storage (AF), reservoir overflow (AF), reservoir release (AF), reach flow (cfs), delivered water (i.e. demand met) (AF), shortage (demand – delivered water) (AF), net downstream return flow (AF), and total reused water (AF). The model also provides summary statistics (average, minimum, and maximum) for each output parameter.

3.) Model Equations:

The following calculations are performed at each timestep for the simulation duration. For simplicity, example equations given here assume an annual timestep (but the same calculations are performed for monthly timestep simulations).

Supply:

The first thing calculated in the model is the incoming available water for the given timestep, both consumptive use water and total:

$$inflow\_CU = baseflow\_annual * baseflow\_CU + ag\_CU * ag\_lands + nonAg\_transfer \quad (3\text{-}1)$$

&

$$inflow\_tot = baseflow\_annual + nonAg\_transfer + ag\_CU * ag\_lands / ag\_effic. \quad (3\text{-}2)$$

Note that the consumptive use credits associated with a non-ag water acquisition are assumed to be 100%.

The inflow CU credits are then mixed with the existing storage CU credits (for reservoir option) to get the percent CU associated with the direct water supply source, according to:

$$percentCU\_source = inflow\_CU / inflow\_tot * (inflow\_tot / (inflow\_tot + res\_vol\_prev)) + res\_prevVol\_CU * (res\_vol\_prev / (inflow\_tot + res\_vol\_prev)), \quad (3\text{-}3)$$

where res_vol_prev = the reservoir storage at the beginning of the timestep and res_prevVol_CU = the percent CU associated with this existing reservoir storage. The calculation in Equation 3-3 is required for properly tracking the CU credits in the water supply.

For the reach option, the equation is simply:

$$percentCU\_source = inflow\_CU. \quad (3\text{-}4)$$

Usage & Demand:

The next set of calculations in the model evaluate the impacts of conservation and reuse on the M&I usage and demand. In this model, usage is considered the actual amount of water used or applied during a given timestep, while demand is considered to be the net external water requirement (i.e. how much water actually needs to be brought into the system to meet that usage).

Indoor and outdoor usage values are calculated using the percent indoor and percent outdoor uses (percent outdoor is calculated as 100% – percent indoor). Changes in annual usage due to climate changes are calculated as:

$$total\_outuse\_annual = total\_outuse\_annual * (climate\_adjust^{YR}) \tag{3-5}$$

where "YR" is the year number since the start of the simulation (starting with yr = 1).

Conservation impacts, which are considered reductions in *usage*, are calculated with the following:

$$total\_inuse\_annual = total\_inuse\_annual * (1 - conservIn\_reduct\_annual) \tag{3-6}$$

&

$$total\_outuse\_annual = total\_outuse\_annual * (1 - conservOut\_reduct\_annual) \tag{3-7}$$

Similar to the CU tracking performed on the source water, consumptive use requirements for the demands must also be calculated. This equation, which calculates the net consumptive use percentage in the demand, is written as:

$$percentCU\_annual = percentCU\_annual\_in *(total\_inuse\_annual / total\_use\_annual) + percentCU\_annual\_out * (total\_outuse\_annual / total\_use\_annual). \tag{3-8}$$

Reuse is a demand management scheme that effectively reduces the external water *demand* of a user (or group of users) for a given total usage. The governing equation is:

$$demand = total\_use\_annual - reuse \tag{3-9}$$

where all terms can be expressed as acre-feet (AF) of water, and reuse is the total amount of water that gets reused.

For exchange reuse schemes, the model assumes reuse is carried out to extinction (or at least close to extinction). In other words it gets reused multiple times, with losses/consumption at each application, until it is essentially completely consumed. These additional iterations of reuse (beyond the 1st reuse) are simulated with a calculated reuse multiplier. In other words, the reuse multipliers are used in calculating the amount of additional reuse water that can be derived in a reuse program after the 1st time reuse (i.e. the return flows from the reuse applications are iteratively captured and reused multiple times). This parameter is calculated as a function of the user-input return flow associated with exchange reuse, according to:

$$reuse\_multiplier\_exch = \sum_{i=1}^{i=10} \frac{(returnFlow\_exch)^i}{returnFlow\_exch}. \tag{3-10}$$

Note that Equation 3-10 assumes that the incrementally smaller return flows can realistically be exchanged ten times, thus we use 10 terms in the series (rather than the theoretical maximum of an infinite series). Because we assume that irrigation return flows cannot be captured, the reuse multiplier associated with this type of reuse scheme is simply 1.0, or

$$reuse\_multiplier\_irr = 1.0 \qquad (3\text{-}11)$$

Since the model allows for a combination of recapture and exchange reuse (with the combined reuse percentage not to exceed 100 %), a weighted average reuse multiplier is calculated as:

$$net\_multiplier = reuse\_multiplier\_irr * (reuse\_recap / total\_reuse) + reuse\_multiplier\_exch * (reuse\_exch / total\_reuse), \qquad (3\text{-}12)$$

where

$$total\_reuse = reuse\_recap + reuse\_exch. \qquad (3\text{-}13)$$

Equation 3-9 can therefore be written as:

$$demand = total\_use\_annual - net\_multiplier * (1^{st}\ time\ reuse\ water). \qquad (3\text{-}14)$$

The 1st time reuse water (AF) is calculated based on user-input percent reuse values and the actual amount of water available for reuse. The amount of water available for reuse is a function of the non-CU usage (only non-CU water can be reused) and the CU credits associated with this non-CU water. Only water for which there is CU credit can be reused. These calculations can be summarized as:

$$1^{st}\ time\ reuse\ water = total\_reuse * extra\_CU, \qquad (3\text{-}15)$$

and

$$extraCU = percentCU\_source * demand - percentCU\_annual * total\_use\_annual. \qquad (3\text{-}16)$$

Equations 3-9 through 3-16 can be rearranged and easily solved for demand, according to:

$$demand = total\_use\_annual * (1 + net\_multiplier * total\_reuse * percentCU\_annual) / (1 + net\_multiplier * total\_reuse * percentCU\_source), \qquad (3\text{-}17)$$

However, when the available consumptive use percentage (percentCU_source) is less than the percent CU of the demand (percentCU_annual), the water requirement is limited by meeting the M&I consumptive use and there are no “extra” consumptive use credits available for reuse. For this case, reuse = 0 and the demand is simply the total usage, or:

$$demand = total\_use\_annual. \quad (3\text{-}18)$$

Storage:

For the reservoir source option, storage is calculated using a simple flow balance:

$$dS/dt = inflow - outflow, \quad (3\text{-}19)$$

where S is the reservoir storage volume and t is time. In the model, this equation is applied according to:

$$res\_vol = res\_vol\_prev + inflow\_tot - res\_release - demand\_met - evap \quad (3\text{-}20)$$

where

$$demand\_met = demand \text{ (initially, see below)} \quad (3\text{-}21)$$

and

$$evap = evap\_rate\_annual(in./yr) * 365 / 12 * (res\_area\_prev + res\_area)/2 \quad (3\text{-}22)$$

or

$$evap = evap\_rate\_annual(\%vol) * (res\_vol\_prev + res\_vol)/2. \quad (3\text{-}23)$$

Since evaporation rates are a function of current reservoir volumes, Equation 3-20 is non-linear. Therefore, the following steps are followed in solving for res_vol:

- Equation 3-20 is linearized by assuming evap = 0,
- If necessary, this value is used to calculate res_area (according to the user-defined vol:area table),
- Equations 3-22 or 3-23 are applied to estimate evap,
- res_vol is recalculated with Equation 3-20 using this estimated evap value.

If the calculated storage volume is greater than the reservoir capacity, then overflow is calculated as:

$$res\_overflow = res\_vol - res\_capacity \quad (3\text{-}24)$$

and

$$res\_vol = res\_capacity. \quad (3\text{-}25)$$

Alternatively, if the calculated storage is less than the user-defined storage minimum, then demand met is reduced until the minimum storage limit is reached. If evap alone causes the storage volume to drop below the minimum, then demand_met = 0.

For the reach source option, the instream flow is calculated as:

reach_flow = inflow_tot – demand_met - reach_losses. (3-26)

As above, demand_met in this equation is initially set equal to the demand calculated above. However, if the reach_flow calculated in Equation 3-26 is below the minimum required flow, then demand_met is reduced until this constraint is satisfied.

Shortage and Return Flows:

A shortage, in terms of meeting M&I demand, occurs when demand_met is constrained by the combination of available inflows and either reservoir or reach minimum storage requirements. Shortage is calculated as:

shortage = demand - demand_met. (3-27)

When there is no reuse occurring, the net return flow is simply the non-CU portion of the used water or:

*net_returnFlow = (1 - percentCU_annual) * demand_met.* (3-28)

However, when there is reuse, the calculations get slightly more complicated. For the case where the net demand has been met (shortage = 0), the equation is:

*net_returnFlow = demand - percentCU_annual * total_use_annual*
- reused_water, (3-29)

where

reused_water = 1^{st} *time reuse = extra_CU * total_reuse.* (3-30)

In other words, the returned flow is equal to the delivered water minus the consumed water minus the water that gets consumed during reuse.

For the case where there *is* a shortage, the equation is:

*net_returnFlow = demand_met - percentCU_annual * total_use_annual*
** demand_met / demand - reused_water,* (3-31)

where reused_water is calculated according to Equation 3-30, but extra_CU is calculated as:

*extra_CU = demand_met * percentCU_source - percentCU_annual **
*total_use_annual * demand_met / demand.* (3-32)

The underlying assumption in Equations 3-31 and 3-32 is that the percent CU in M&I usage stays the same even during times of shortage.

Finally, for reservoir storage, the downstream return flow is augmented by the reservoir release, or:

net_returnFlow = net_returnFlow + res_release. (3-33)

4. Model limitations and key assumptions

Key model assumptions are:

- For ag transfers, users can transfer the farm headgate water when retiring ag lands. In other words the amount of water rights acquired depends on how much the farmer was getting at his headgate, which includes water that is lost on the farm or returned from the farm. The ag efficiency can be thought of as the consumed water divided by the headgate water. Note that the farm headgate water is generally less than the actual water diverted from the source (i.e. the river headgate water), which includes ditch loss (from river to farm headgate).

- Users only gets consumptive use credits for the water consumed on the farm, not the headgate water.

- For non-Ag acquisition, all water is 100% consumable.

- Percent reuse for irrigation and exchange/augmentation, as well as the percent return flows associated with these reuse options, are assumed constant through the year.

- The percent CU in usage does not change during times of shortage.

- The yields from reuse programs are realized immediately (i.e. there is no lag from initiating reuse to when additional water is actually available).

- Recaptured reuse (effluent) is only used for irrigation.

Attachment A
Reuse and Ag Transfer Schematic Diagrams

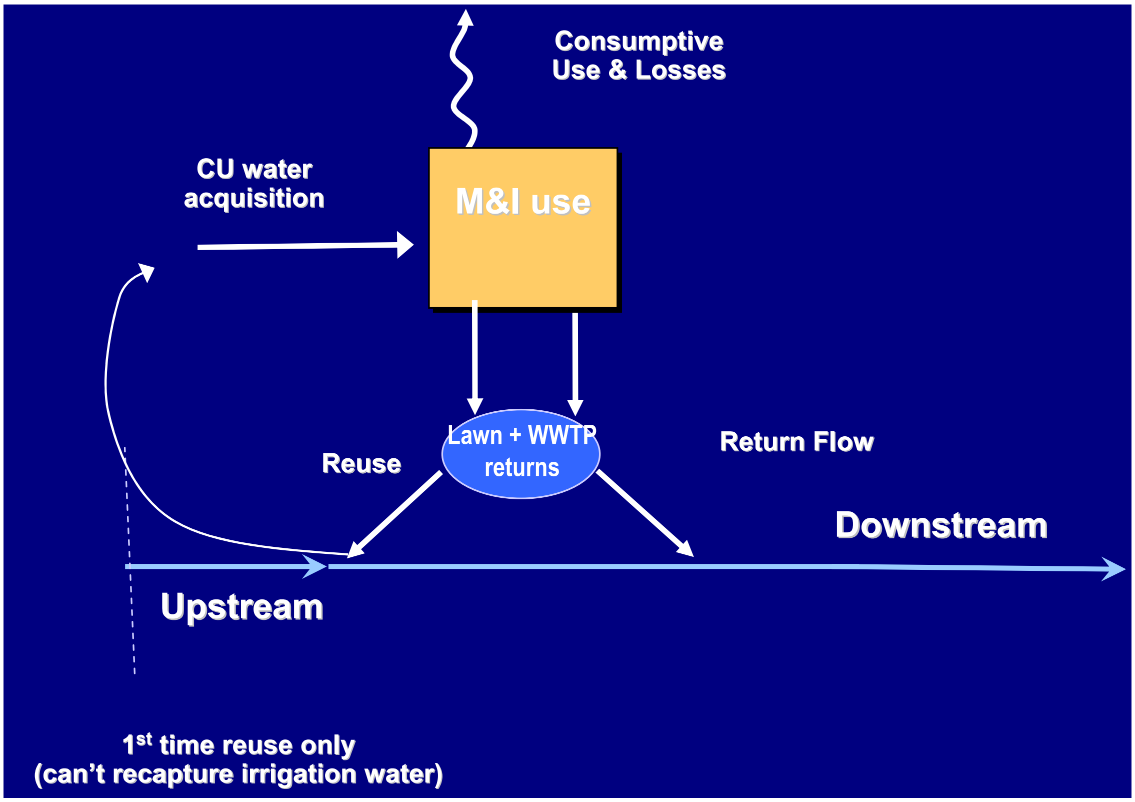

Figure A-1
Recapture Reuse (for Irrigation)

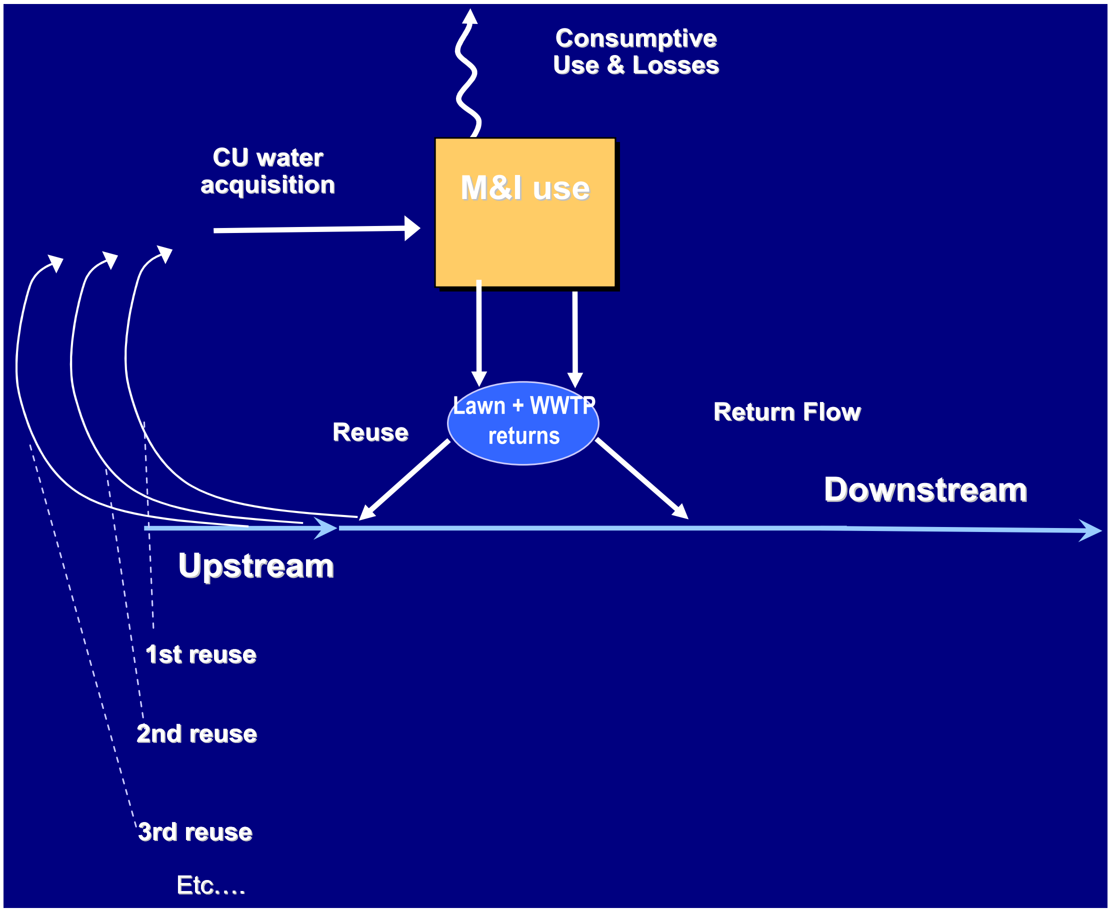

Figure A-2
Exchange Reuse (for Indoor or Outdoor Use)

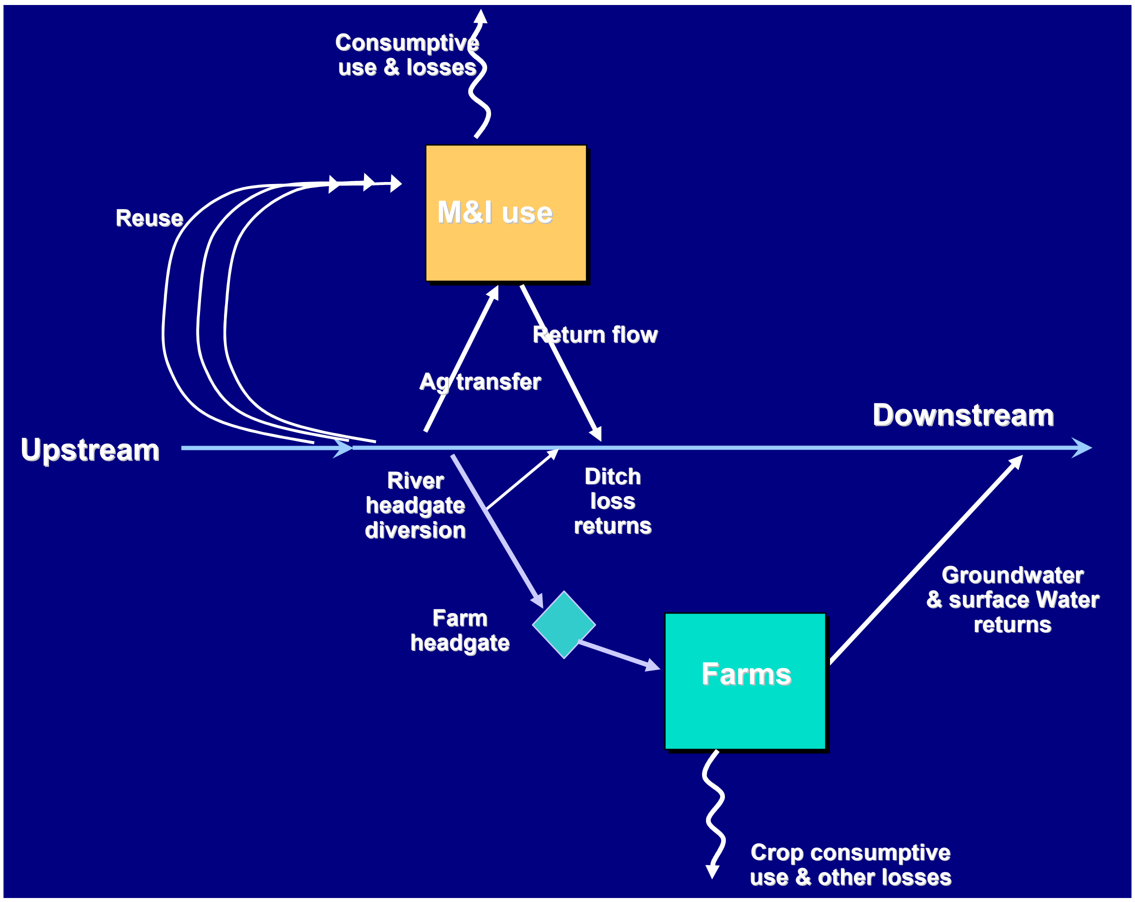

Figure A-3
Ag Transfer with Exchange Reuse

Attachment B
Reuse and Ag Transfer Schematics with Calculated Values

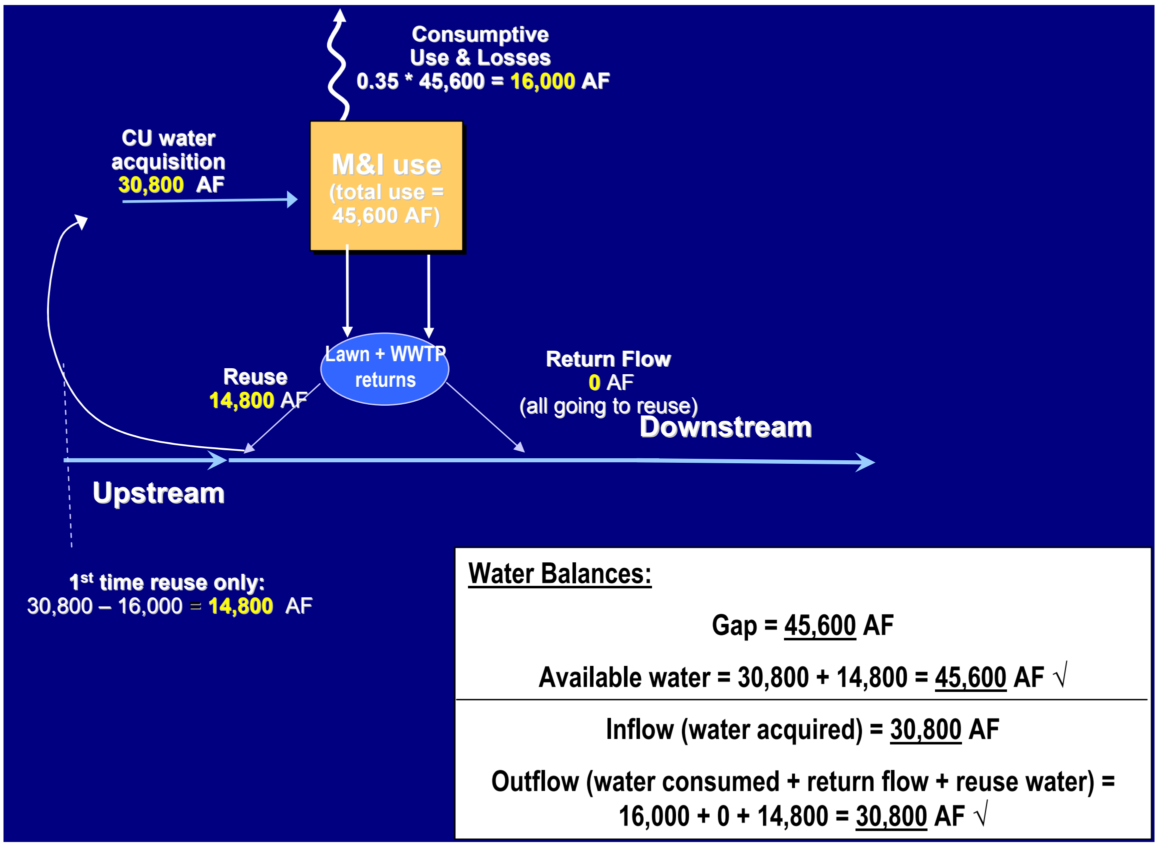

Figure B-1
Recapture Reuse (for Irrigation)

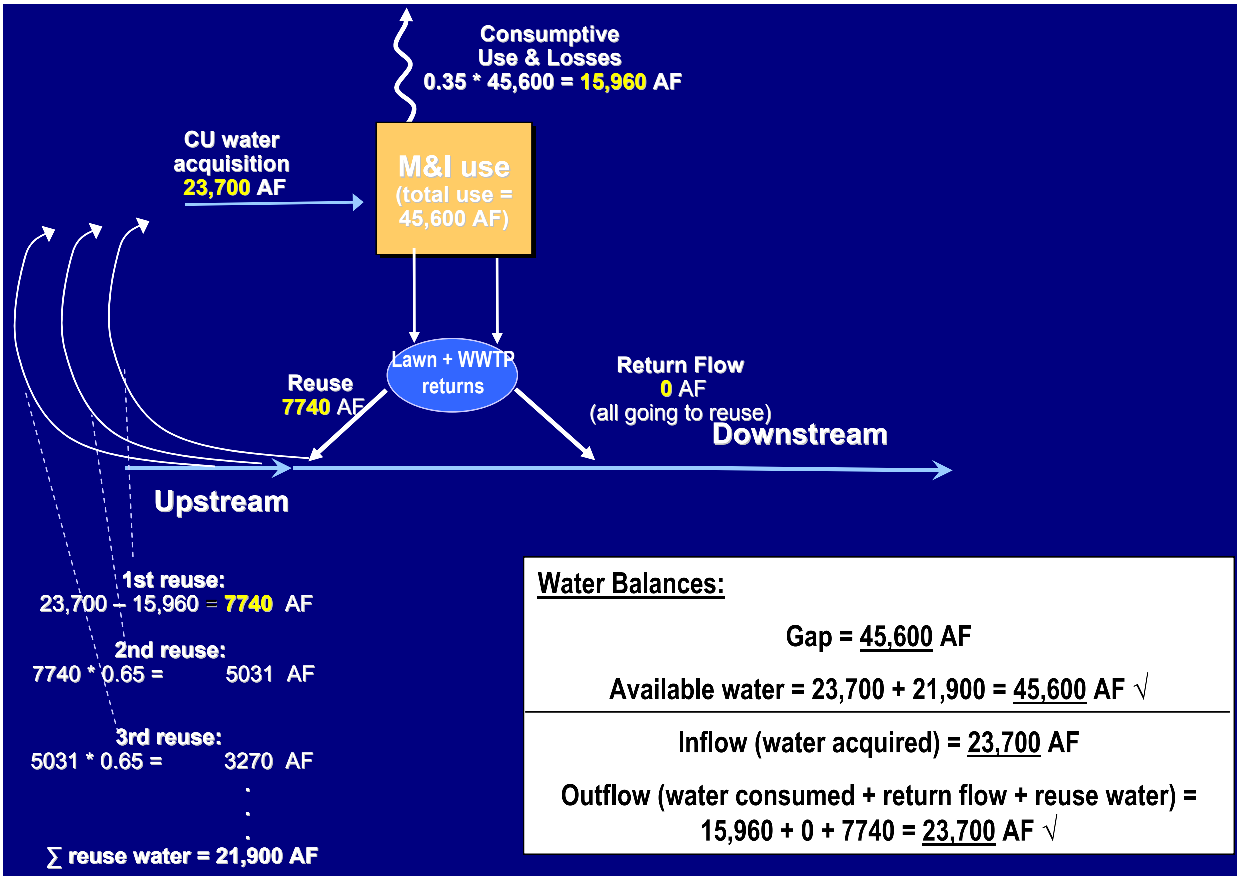

Figure B-2
Exchange Reuse (for Indoor or Outdoor Use)

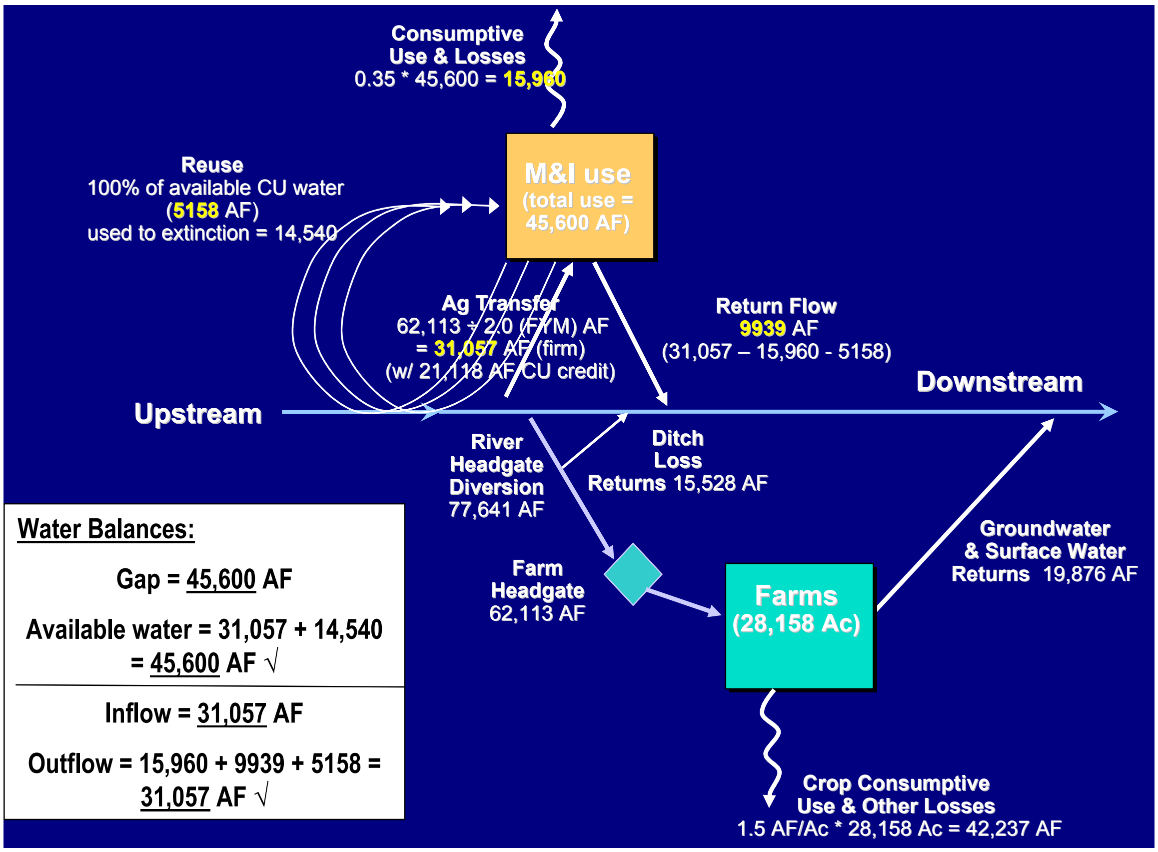

Figure A-3
Ag Transfer with Exchange Reuse