Technical Memorandum

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Date: *June 28, 2011*

Subject: *SWSI 2010 Portfolio and Trade-off Tool Documentation*

The purpose of this memo is to describe the Colorado Water Conservation Board's (CWCB) Statewide Water Supply Initiative (SWSI) 2010 Portfolio and Trade-off Tool (tool) and to provide basic documentation on the components of the tool. The memo describes the following components of the tool:

M&I Water Needs:
- Municipal and Industrial (M&I) Needs
- Self-Supplied Industrial (SSI) Needs
- Oil Shale Development Water Needs
- Passive Conservation
- Demand/Supply Factor

Portfolio Elements:
- Identified Projects and Processes (IPPs) Yield
- Active Conservation
- Agricultural Transfers and Reuse
- New Supply Development and Reuse

Trade-Offs:
- Decreases in Irrigated Acres
- Estimate of Colorado River Depletions
- Size of Alternative Agricultural Transfer Program
- Cost estimates for user defined portfolio compared to status quo portfolio
- Non-consumptive Trade-off for West Slope

M&I Water Needs

The tool calculates water needs between 2008 and 2050 based on the following:

- Municipal and Industrial (M&I) Needs
- Self-Supplied Industrial (SSI) Needs
- Oil Shale Development Water Needs
- Passive Conservation
- Demand/Supply Factor

Figure 1 below shows the tool's scenario builder tab where the user can modify the M&I Demand Scenarios.

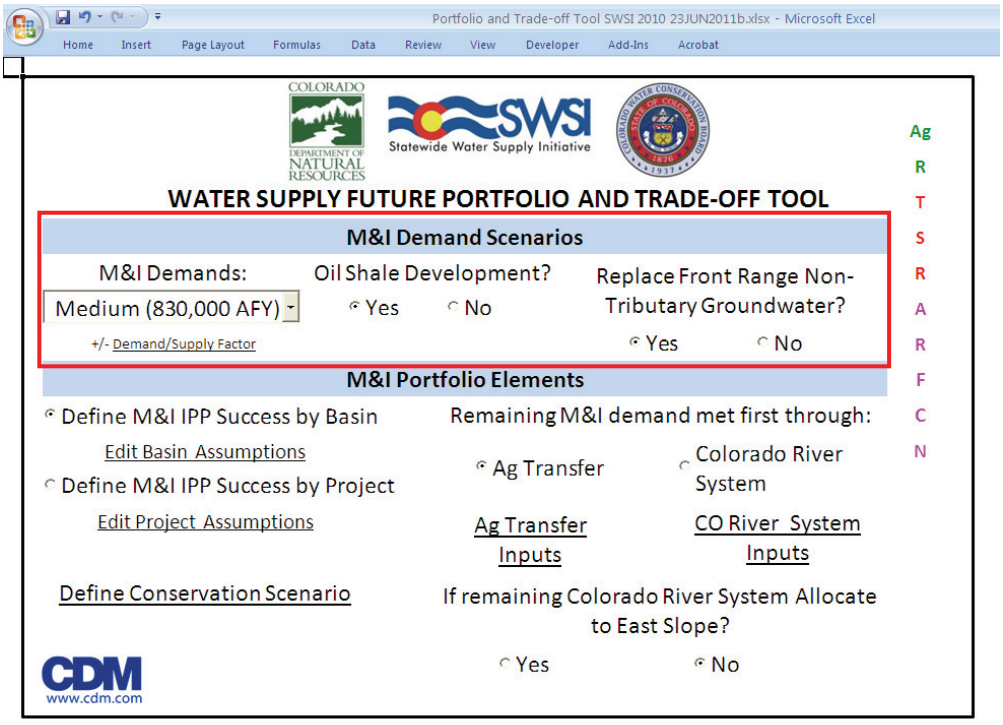


Figure 1 Varying M&I Demands can be Examined from the Scenario Builder Tab

M&I and SSI 2050 Needs

The source of data for the M&I and SSI 2050 needs is the SWSI 2010 Report (CWCB 2011). To determine 2050 low, medium, or high new water needs based on tool selections, the 2008 M&I estimates are subtracted from the 2050 low, medium, or high M&I estimates. Similarly, the SSI 2050 needs are calculated by subtracting the 2008 SSI needs from the 2050 low, medium, or high estimates.

The tool also includes the replacement of nonrenewable groundwater in the South Metro area of Denver and unincorporated El Paso County. These are included as additional needs to be met by 2050 in the tool. The tool assumes that 20,900 acre-feet per year (AFY) will need to be replaced for the South Metro and 13,400 AFY for unincorporated El Paso County for a total of 34,300 AFY statewide.

Oil Shale Water Needs

Oil shale water needs were summarized in SWSI 2010 (CWCB 2011). Build-out oil shale water demands are included in the tool and included as Table 1. Table 1 summarizes the total indirect and direct water demands for the build-out industry scenario of 1.5 million barrels/day *in situ* production and 50,000 barrels/day above-ground production. This table shows build-out direct water demands for the low, medium, and high scenarios defined in Phase 2 of the Energy Study. The low scenario is presented as a negative number due to subtracting the amount of water that is produced as a byproduct of shale oil production (Colorado, Yampa, and White River Basin Roundtables Energy Subcommittee 2010). In the tool, the low demand scenario is included as a 0 AFY demand. The scenarios are matched with the low, medium, and high M&I demand scenarios.

Table 1 Water Demand Scenarios for Oil Shale

Scenario	Colorado Basin		Yampa-White Basin		Total (AFY)
	SSI (AFY)	M&I (AFY)	SSI (AFY)	M&I (AFY)	
Low	0	0	0	0	**0**
Medium	4,200	6,200	46,000	2,600	**59,000**
High	9,100	4,900	104,000	2,000	**120,000**

Passive Conservation

The tool currently includes a non-optional portfolio element of passive conservation. The CWCB Water Conservation and Drought planning section recently updated the passive conservation calculations for SWSI 2010 (CWCB 2011). Table 2 below shows the passive conservation savings by basin from SWSI 2010. These passive savings are subtracted from the M&I Needs for each basin. as shown in Figure 2, which is an output example from the tool.

Table 2 Passive Conservation Savings by Basin

Basin	Passive Conservation Savings (AFY)
Arkansas	29,000
Colorado	10,000
Gunnison	4,000
Metro	75,000
North Platte	100
Rio Grande	1,000
South Platte	30,000
Southwest	4,000
Yampa/White	1,000

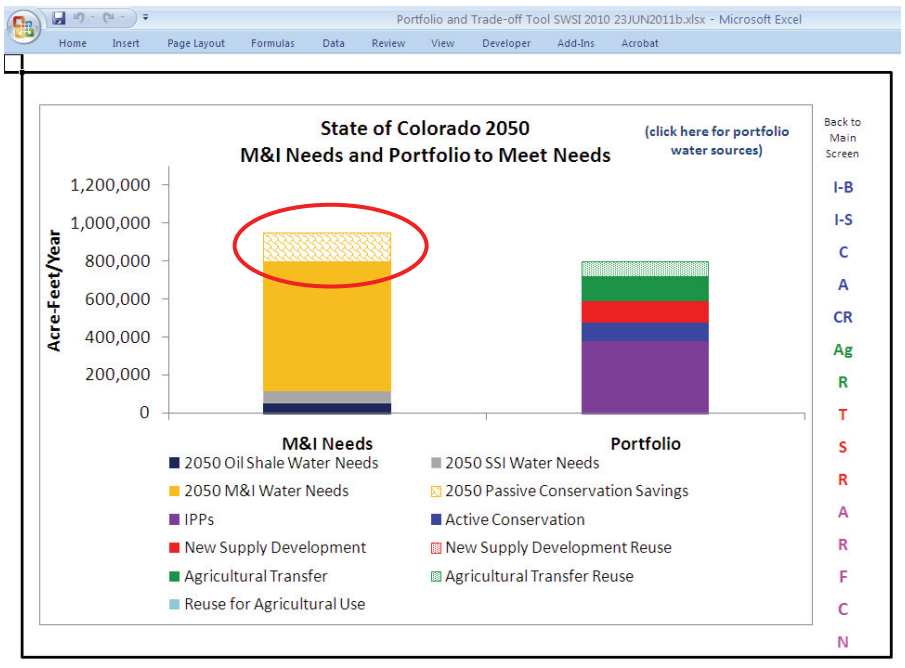
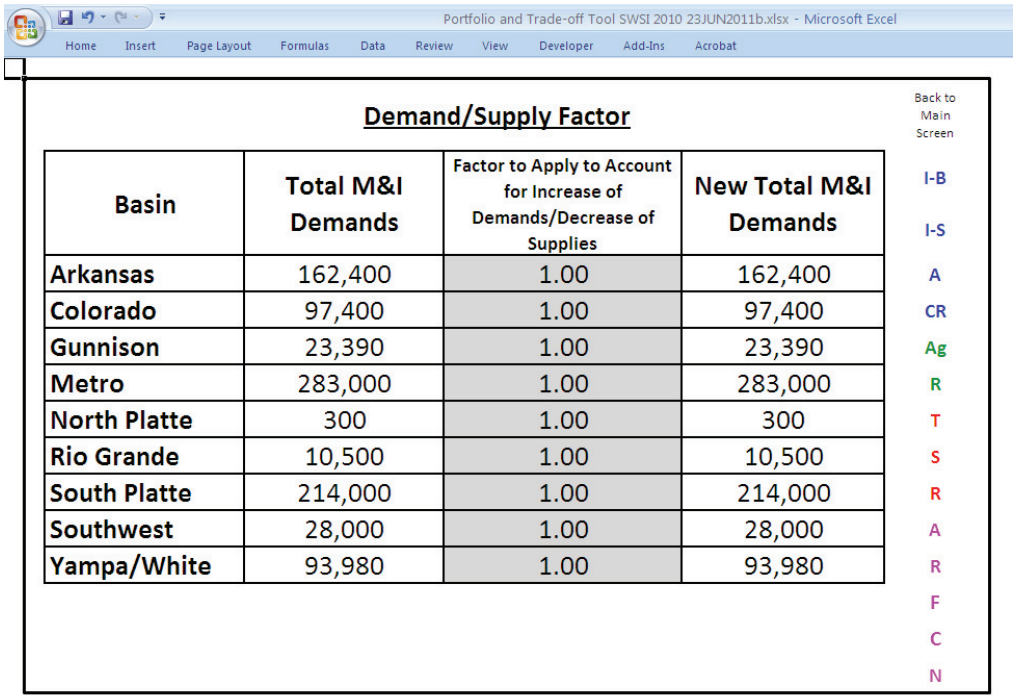


Figure 2 Example Portfolio Showing Reduction in M&I Demands from Passive Conservation

Demand/Supply Factor

Figure 1 on page 2 of this technical memorandum shows that in the M&I Demand Scenarios portion of the tool's main screen the user can add a +/- demand supply factor. When clicking on the link, the user is brought to the screen shown in Figure 3. As shown in Figure 3, the user can account for an increase in demands or decrease in existing supply for a given basin to account for uncertainties such as climate change, loss of existing supplies, or other basin specific risk factors by setting the factor to greater than 1.0. Alternatively, the user can decrease demands by setting the factor to be less than 1.0. The user can only change the cells in grey on this input screen.



Basin	Total M&I Demands	Factor to Apply to Account for Increase of Demands/Decrease of Supplies	New Total M&I Demands
Arkansas	162,400	1.00	162,400
Colorado	97,400	1.00	97,400
Gunnison	23,390	1.00	23,390
Metro	283,000	1.00	283,000
North Platte	300	1.00	300
Rio Grande	10,500	1.00	10,500
South Platte	214,000	1.00	214,000
Southwest	28,000	1.00	28,000
Yampa/White	93,980	1.00	93,980

Figure 3 Demand/Supply Factor Input Screen

Portfolio Development

The tool allows users to develop portfolios based on the 2050 water needs for the low, medium, or high scenarios. The portfolio elements are:

- IPPs Yield
- Active Conservation
- Agricultural Transfers and Reuse
- New Supply Development and Reuse

Each of these portfolio elements can be accessed via the "Scenario Builder" tab of the tool as show in Figure 4.

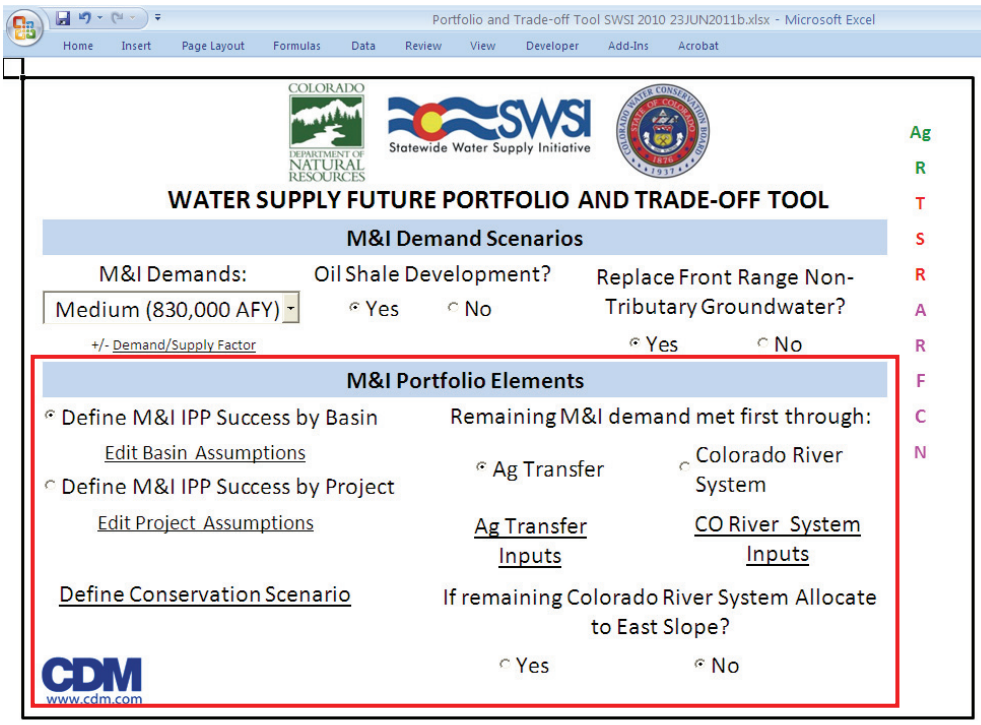
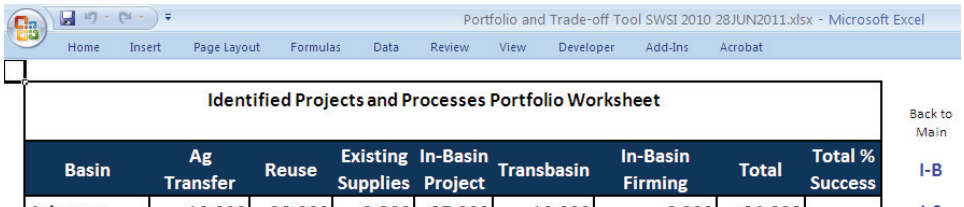


Figure 4 M&I Portfolio Elements Options

Identified Projects and Processes Yield

In the tool, the user has the option to implement IPPs at the basin level or by individual IPPs. This selection is made on the "Scenario Builder" tab by selecting "Define M&I IPP Success by Basin" or "Define M&I IPP Success by Project." If the user decides to implement IPPs at the basin level, the user has the option to set a success rate for the yield of the IPPs for each IPP type (ag transfer, reuse, existing supplies, in-basin project, transbasin and in-basin firming). This information was developed using data from SWSI 2010 (CWCB 2011). The user can set the percent success of the yield for each IPP type at the basin level in the tool as shown in Figure 5.



Identified Projects and Processes Portfolio Worksheet

Back to Main

Basin	Ag Transfer	Reuse	Existing Supplies	In-Basin Project	Transbasin	In-Basin Firming	Total	Total % Success
Arkansas	10,000	28,000	2,300	37,000	10,000	6,800	94,000	90%
% Success	90%	90%	90%	90%	90%	90%	85,000	
Colorado	4,800	540	20,000	15,000	0	14,000	54,000	91%
% Success	90%	90%	90%	90%	90%	90%	49,000	
Gunnison	430	0	1,300	13,000	0	900	16,000	88%
% Success	90%	90%	90%	90%	90%	90%	14,000	
Metro	24,000	17,000	65,000	35,000	17,000	1,100	160,000	75%
% Success	50%	90%	100%	50%	50%	50%	120,000	
North Platte	0	0	190	0	0	0	190	89%
% Success	90%	90%	90%	90%	90%	90%	170	
Rio Grande	0	0	3,500	0	0	3,500	7,000	90%
% Success	90%	90%	90%	90%	90%	90%	6,300	
South Platte	19,000	5,900	24,000	38,000	19,000	24,000	130,000	62%
% Success	50%	100%	100%	50%	50%	50%	80,000	
Southwest	0	0	6,200	11,000	0	0	17,000	100%
% Success	100%	100%	100%	100%	100%	100%	17,000	
Yampa White	0	0	4,000	7,900	0	0	12,000	100%
% Success	100%	100%	100%	100%	100%	100%	12,000	

I-B
I-S
C
A
CR
Ag
R
T
S
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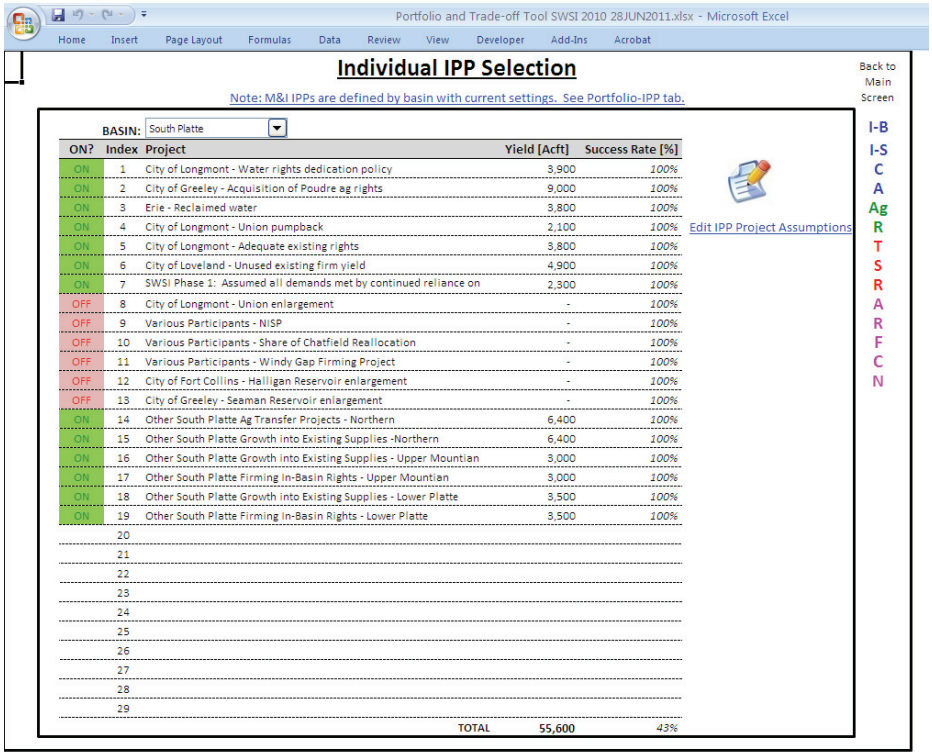
Figure 5 IPP Yield by Type and Basin

The tool also allows the user the option to identify specific IPPs to include in the portfolio and define their respective success rate. There is a master list of IPPs containing the project name, basin, type of project, and the anticipated yield. Based upon the selected IPPs and other user defined success rates the tool calculates the total IPP yield for a basin. This list is stored in the "IPP Master List" tab. These two tool tabs are shown in Figure 6.



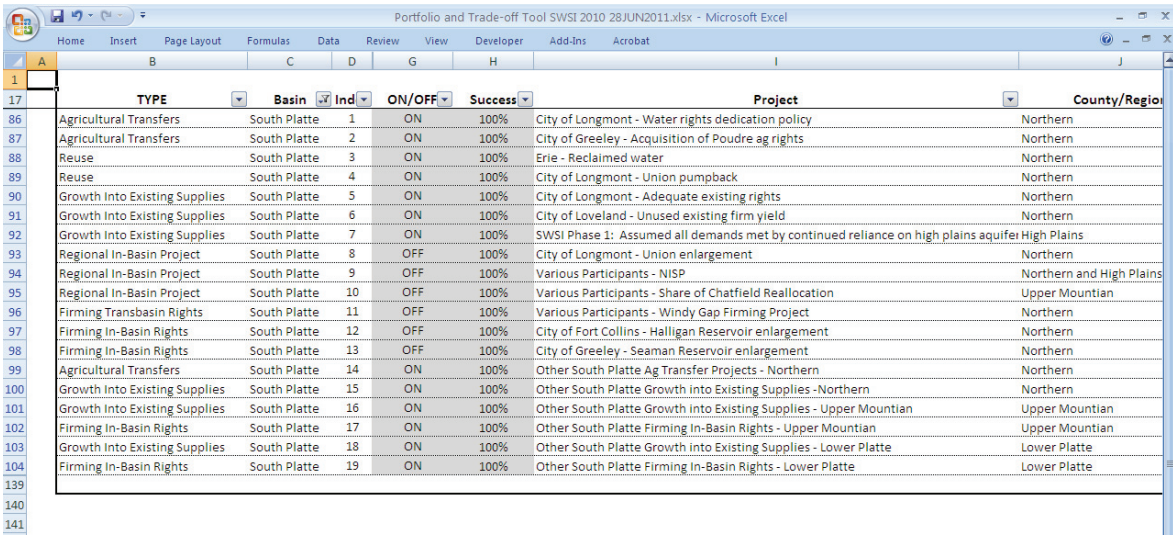
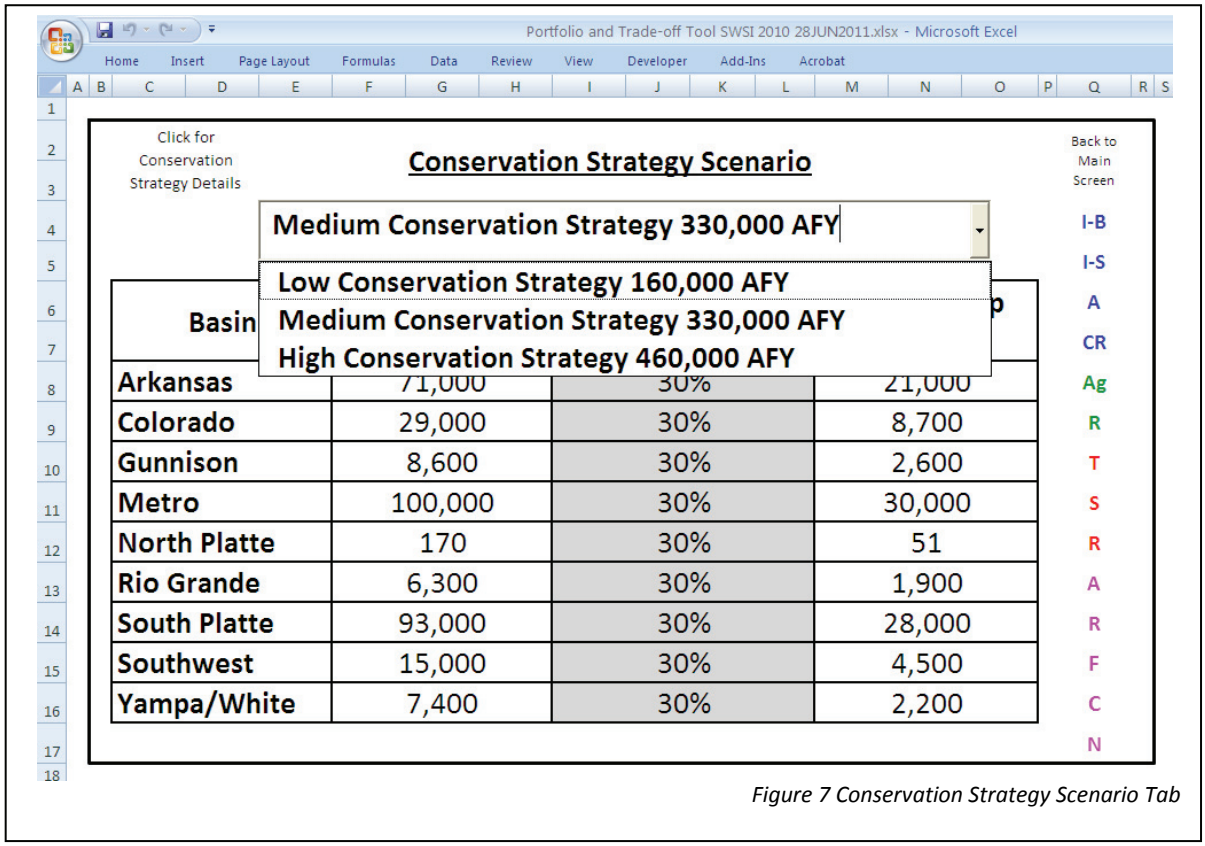


Figure 6 IPP Yield by Individual IPP Tool Tabs

Active Conservation

As part of SWSI 2010 (CWCB 2011), a conservation strategy was developed that estimated conservation savings on a low, medium, and high basis for each of the Basin Roundtable areas. The tool allows the user to select a conservation strategy (low, medium or high) and define the percentage of the yield to be applied to the gap by basin by changing the grey cells shown in Figure 7. The statewide conservation savings amounts range from 160,000 to 460,000 AFY as shown in Figure 7. In addition, by clicking on the "Click for Conservation Strategy Details" link, the user can view the SWSI 2010 table that describes the types of conservation measures included in each strategy.



Basin			
Arkansas	71,000	30%	21,000
Colorado	29,000	30%	8,700
Gunnison	8,600	30%	2,600
Metro	100,000	30%	30,000
North Platte	170	30%	51
Rio Grande	6,300	30%	1,900
South Platte	93,000	30%	28,000
Southwest	15,000	30%	4,500
Yampa/White	7,400	30%	2,200

Figure 7 Conservation Strategy Scenario Tab

Agricultural Transfers and New Supply Development

The tool subtracts the IPPs and active conservation from the 2050 water needs. The remaining water needs can be filled either first from agricultural transfers or new supply development. This is a user option specified in the tool. When filling first with agricultural transfers, the user can specify the amount of irrigated acres per basin that would be available for conversion to M&I use. These are calculated using the agricultural transfer options as described below. The amount of reuse for the consumable portion of the agricultural transfer is also included in the portfolio. The amount of reuse is calculated using a reuse multiplier that is described in the reuse options below. After the agricultural transfer and reuse yields are determined, these are subtracted from the remaining water needs. If there are still water needs then new supply development is utilized to fill the remaining gap.

If the user chooses to fill the remaining water needs with new supply development first, the amount of water from the Colorado River System available to fill the need is based on a user-generated value. Reuse of any transfers of Colorado River System to the East Slope is included in the portfolio as described below. After the new supply development and reuse yields are determined, these are subtracted from the remaining water needs. If there are still water needs after the use of new water supplies, then agricultural transfers are utilized to fill the remaining gap. The tool also allows the user to specify that if additional Colorado River Water is not fully utilized on the West Slope, it could be transferred to the East Slope. Finally, if the amount of Colorado River and associated reuse exceeds what is needed to meet the M&I needs on the East Slope, the excess water is noted as available for use by agriculture in the portfolio output.

Agricultural Transfer Options

The agricultural transfer options in the tool allow the user to set the amount of transferrable consumptive use in AF per acre. There are several factors that impact yields from an agricultural transfer. Some of these factors include:

- Priority of water right (senior vs. junior)
- Physical availability
- Historical use
- Ditch and irrigation efficiencies
- Cropping patterns
- Return flow obligations (location, amount, and timing)
- Firming storage needed to provide meaningful yield for all but the most senior water rights

The tool uses a default of 1.3 AF per acre for transferable consumptive use rate for all basins but the user can specify a different rate in the “Options-Ag Transfer” tab. Historically in the South Platte Basin, the transferrable range of consumable water has approximated 0.8 AF per acre to 1.7 AF per acre.

The transfer yields described above are considered an average yield. To make sure that the yield is on a firm basis, a safety factor is included in the tool that allows the user to specify an additional percentage of additional irrigated acres that would need to be firm supply. The tool currently uses a default of 25 percent for the average to firm yield safety factor.

Following is a description of how these options are used in calculations in the tool. If the user specifies that 1,000 irrigated acres are to be transferred to M&I use, the calculation to estimate a firm yield of supply would be:

1000 acres * 1.3 acre-feet/acre * (1 – 0.25) = 975 acre-feet

Similarly if the tool estimates the amount of yield from agricultural transfers needed to fulfill 2050 water needs, the amount of irrigated acres needed to transfer to M&I uses is calculated. For example, if the tool estimates that 1,000 AF are needed to fill a need, then the calculation to estimate the number of irrigated acres would be:

1000 acre-feet / (1.3 acre-feet/acre * (1-0.25)) = 1025 acres

In addition, the user is able to specify the percentage decrease from average to firm yield for water transferred from agricultural use in the "Options-Ag Transfer" tab. The default is set at 25 percent.

Reuse Options

The tool allows the user to individually vary the percent of reuse on the East Slope and the West Slope from 0 percent to 100 percent. That percentage can be further subdivided into reuse by exchange or direct recapture (non-potable) reuse in split percentages summing to 100 percent, e.g., 70/30 or 45/55.

M&I reuse by water rights exchanges involves the exchange of legally reusable return flows for water diverted at a different location. Water is diverted at one source in exchange for water replaced to downstream users from a different source. In an M&I reuse exchange, the amount of non-consumptive use (CU) water returned to the system, e.g., via effluent flows and/or return flows from landscape irrigation, depends on the CU associated with the demand (i.e., the higher the CU, the lower the percent of total diversions that can be reused).

Non-potable reuse involves the capture and use of legally reusable return flows for the irrigation of urban landscapes or for industrial uses such as cooling or process water. Since return flows from landscape irrigation are hard to capture in one location, non-potable reuse to date has involved the reuse of consumable effluent discharged from wastewater treatment facilities. The effluent undergoes additional treatment to meet non-potable reuse standards. This treatment usually involves filtration and additional disinfection.

The tool uses multipliers at the basin level for the amount of consumable water that is reused as shown in Table 3. The user can set the percentage of reuse achieved basin wide and then specify the amount of that reuse that is by exchange or through non-capture. A weighted average is then used to establish a total multiplier for the basin. For example, if 100 AF are available in a basin to reuse and 50 percent of that amount is reused by equal parts exchange and non-capture, then the weighted average multiplier would be 1.45 [(0.5*1.6+0.5*1.3]. Therefore yield of the reused water is 45 AF (100*1.45-100).

Table 3 Total Yield After Reuse by Exchange or Recapture

Percent of Consumable Supplies Reused	Exchange Reuse Multiplier [AF]	Non-Capture Reuse Multiplier [AF]
0%	1.0	1.0
5%	1.1	1.0
10%	1.2	1.1
15%	1.2	1.1
20%	1.3	1.1
25%	1.4	1.1
30%	1.4	1.2
35%	1.5	1.2
40%	1.5	1.2
45%	1.6	1.3
50%	1.6	1.3
55%	1.7	1.3
60%	1.7	1.3
65%	1.7	1.3
70%	1.8	1.4
75%	1.8	1.4
80%	1.8	1.4
85%	1.8	1.4
90%	1.9	1.4
95%	1.9	1.5
100%	1.9	1.5

Summary of M&I Needs and Portfolio Elements

Based on the user defined options described above, the tool displays a table and charts summarizing the M&I water needs and the associated user-defined portfolio for the given demand scenario. The charts are summarized at a state, regional, and basin-by basin basis. In addition, the user can see the water sources for the entire portfolio based on the IPP types described previously. This information is available at the state and basin level.

Trade-offs in Tool

Based on the M&I demand scenario and associated user defined portfolio, the tool displays the following trade-offs in graphical form:

- Decreases in Irrigated Acres
- Estimate of Colorado River Depletions
- Size of Alternative Agricultural Transfer Program
- Cost estimates for user defined portfolio compared to status quo portfolio
- Non-consumptive Trade-off for West Slope

Decreases in Irrigated Acres

The first trade-off in the tool is an analysis that shows the amount of decreases in irrigated acres at the state and regional level and is based on the estimated yield of agricultural transfers as described above in the portfolio development. The amount of irrigated acres are estimated using the equations described in the above Agricultural Transfer Options section.

Colorado River Depletions

The tool estimates Colorado River Depletions by completing the following assumptions:

- New Supply Development transferred to the East Slope is 100 percent consumptive
- Self-Supplied Industrial and Energy Uses on the West Slope are 100 percent consumptive
- Municipal and Industrial Use on the West Slope is 35 percent consumptive
- Current depletions are assumed to be 2.634 MAF based on data from the Colorado Decision Support System (CDSS)

Additional future depletions such as IPPs can be added to the tool but are not included at this time. The tool estimates future depletions based on the user defined portfolio and adds these to the current depletions. Estimated future depletions and estimated total depletions are shown in the portfolio table in the tool.

Size of Alternative Agricultural Transfer Program

The tool estimates the size of an alternative agricultural transfer program that would be required to deliver the yield associated with the agricultural transfers portion of the user defined portfolio. Based on work completed by the Super Ditch program in the Arkansas basin and by Northern Colorado Water Conservancy District in the South Platte, the user can define the percentage of lands in the alternative agricultural transfer program that are fallowed at any one time. For example, if the user sets this value to 25 percent, four times the amount of irrigated acres used for a traditional transfer is shown in the trade-off output. This trade-off is available for the East Slope

and West Slope and the user can change the percentage of lands fallowed by clicking on the up/down arrows on each of the trade-off output charts.

Cost Estimates for User-Defined Portfolio

The tool estimates the costs for the user-defined portfolio vs. the status quo portfolio. SWSI 2010 defined the costs for the status quo portfolio and this is presented in Table 4.

Table 4 Status Quo Medium M&I Demand Portfolio (800,000 AF of new water needed)

Strategy	West Slope[1] Unit Cost	West Slope[1] New Water Needed (AF)	West Slope[1] Costs	East Slope Unit Cost	East Slope New Water Needed (AF)	East Slope Costs	Total New Water Needed (AF)	Total Costs
New Supply	$5,900	150,000	$860,000,000	$0	—	$0	150,000	$860,000,000
Ag Transfers	$40,000	3,500	$140,000,000	$40,000	270,000	$11,000,000,000	270,000	$11,000,000,000
IPPs	$5,900	93,000	$550,000,000	$14,000	200,000	$2,900,000,000	290,000	$3,400,000,000
Active Conservation	$7,200	—	$0	$7,200	—	$0	—	$0
Reuse[2]			$0		90,000	$0	90,000	
Total		**240,000**	**$1,600,000,000**		**560,000**	**$14,000,000,000**	**800,000**	**$15,000,000,000**

[1] Costs for the Rio Grande and North Platte Basins are the same as the West Slope and are integrated with the West Slope for the purpose of this cost analysis.

[2] The costs of reuse are incorporated into the costs associated with agricultural transfers or new supply development.

For the user-defined portfolios in the tool the following assumptions are used for estimating the cost of the portfolio:

- IPPs: for construction costs, tool uses $5,900/AF for West Slope projects and $14,000/AF for East Slope projects based on information gathered by CWCB during their effort to update the Basin Needs Decision Support System.

- Conservation: for passive conservation, assumes no cost to water providers and for active conservation, $7,200 based on information developed during SWSI 2010.

- Agricultural Transfer: Assumes a range of $33,500/AF to $34,200/AF construction costs based on size of agricultural transfer. These costs assume a coordinated agricultural transfer project and are based on the cost analysis included in SWSI 2010.

- New Supply Development: Assumes a range of $28,000/AF to $32,200/AF construction costs based on size of new supply development project for transfers to the East Slope. This range is based on costs developed as part of SWSI 2010. New Supply Development on the West Slope

assumes a cost of $5,900/AF based on the same cost assumptions as those associated with West Slope IPPs.

Non-consumptive Trade-Off

To assess potential non-consumptive trade-offs in the tool, CWCB examined changes in flow at four locations on the Colorado River System:

- Blue River downstream of Green Mountain Reservoir
- Gunnison River downstream of Blue Mesa Reservoir
- Yampa River at Maybell, CO
- Green River downstream of Flaming Gorge Reservoir

Three of these locations have on-stream reservoirs – Blue River, Gunnison River, and Green River. Using the CDSS for Blue River, Gunnison River, and Yampa River the CWCB produced natural flow (river conditions minus man made influences), current flow conditions, and potential depletions associated with the user defined portfolio. Because the CDSS does not model flows in Wyoming, a different method was used for the Green River. Assumptions on potential depletions are as follows:

- Blue River downstream of Green Mountain Reservoir: Potential depletions out of Green Mountain Reservoir of 20KAF and 50KAF

- Gunnison River downstream of Blue Mesa Reservoir: Potential depletions of 50KAF, 100KAF, 175KAF, 250KAF

- Yampa River at Maybell: Potential depletions of 50KAF, 100KAF, 175KAF, 250KAF. Since there is no on-channel reservoir on the Yampa River near Maybell, CO it was assumed that depletions would be direct diversions on the main channel.

- Green River downstream of Flaming Gorge Reservoir: Potential depletions of 50KAF, 100KAF, 175KAF, 250KAF. The proportion of downstream depletions from reservoir withdrawals was estimated based on the pattern of flows for the Gunnison River downstream of Blue Mesa Reservoir. Because both are on-channel reservoirs it was assumed for this analysis that similar patterns such as decrease in natural peak flows and increase in late year low flows. Reservoir inflow and outflow data were gathered from flaminggorge.water-data.com. Inflow data were used to estimate natural flows and outflow data were used to estimate current uses

The trade-off tool includes two “environmental flow metrics" set forth in literature and as part of the federal reserve water right for the Gunnison and Rio Grand National Forest in Water Division No. 3. The first metric would allow diversion of 20% of the natural flow for all months of the year. The second metric would allow diversion of 20% of all the natural flow for baseline month (Jan-Apr and Jul-Dec) and 50% of the natural flow during peak flow periods (May-Jul). Richter (2009)

suggests the development of "sustainability boundaries " as described above that are intended to set limits on the extent to which water withdrawals can alter natural variability in water flows and thereby sustaining the social benefits and biodiversity of freshwater ecosystems.[1] The yield estimated from these metrics are displayed in the tool and compared to the East Slope portion of the New Supply Development amount in the user defined portfolio. In addition, Programmatic Biological Opinion triggers are included that are related to depletions that would trigger U.S. Fish and Wildlife consultation in relation to project development in these areas.

[1] Richter, Brian. 2009. Re-thinking Environmental Flows: From Allocations and Reserves to Sustainability Boundaries. River Research and Applications.