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Date: June 7, 2012

RE: **Technical Memorandum 9D – Economic Analysis – *DRAFT***

1.0 INTRODUCTION

The City of Hillsboro (City) is evaluating long-term water supply options that will deliver 80 million gallons per day (mgd) of additional treated water for itself and its Joint Water Commission (JWC) partners. As part of that effort, HDR developed a long-term economic model of the options to evaluate the net present value (NPV) of each option.

This technical memorandum (TM) builds on work completed to date on the following TMs:

- TM 9A defined the individual options and developed capital, and operations and maintenance (O&M) cost estimates;
- TM 9B evaluated the cost risk associated with each option to be incorporated into the Monte Carlo simulations described in this TM; and
- TM 9C described the timing of capital projects.

O&M costs were reported in TM 9A, however, additional information was developed on the split between fixed and variable O&M costs through 2050 and is presented herein.

The purpose of this TM is to combine the information generated in TMs 9A through 9C into the economic evaluation of the water supply options. This draft TM describes the process used for the economic evaluation and the required assumptions. Preliminary economic evaluation results were presented at the Technical Advisory Committee (TAC) meeting on May 22, 2012.

2.0 APPROACH

The approach to the economic evaluation of water supply options uses a statistical technique called Monte Carlo analysis to take into account future risks and uncertainties. The Monte Carlo analysis explicitly integrates these risks and uncertainties into the decision-making process. Monte Carlo analysis is a common statistical technique that relies on repeated random samplings of data to develop results.

Recognizing that the inputs to the model are the best estimates available at this time, rather than certainties, the Monte Carlo analysis assesses the economic evaluation under numerous potential future conditions. The Monte Carlo analysis then provides a range of possible economic outcomes rather than single-point values. It does this by using probability distributions for key inputs rather than simple point values. In each iteration, the software randomly picks a value from each distribution. The outputs from the analyses are probability distributions for the net present value (NPV) of each supply option based on outcomes of 20,000 simulations.

3.0 OPERATIONS AND MAINTENANCE COST BREAKDOWNS

TM 9A provided the O&M costs with additional breakdown provided herein. All treatment costs are based on 2012 budgets for the Joint Water Commission's Water Treatment Plant. Estimated O&M cost breakdowns are described in Table 1.

Table 1: Anticipated Operations and Maintenance Costs

Supply	Costs ($/CCF) [1,2]		
	Fixed	**Chemicals**	**Power[3]**
Tualatin Basin Water Supply Project[4]	$0.32	$0.02	$0.070
Willamette Wilsonville Option	$0.28	$0.02	$0.140
Portland Supply Option[5,6]	$0.28 (treatment) $0.02 (pipelines)	$0.02	$0.015 (Hillsboro portion only)
Newberg West Option	$0.28	$0.02	$0.145
Newberg East Option	$0.28	$0.02	$0.127
Northern Groundwater	$0.33	$0.02	$0.178

(1) CCF – hundred cubic feet of water; mgd – million gallons per day.

(2) All power costs based on total electric load connected at build-out (80 mgd additional capacity) and unit cost of $0.0730/kWh. Cost interpolated linearly for intermediate flows.

(3) Based on total connected electrical loads at build-out as follows: TBWSP – 2,795 kW; Willamette Wilsonville – 8,546 kW; Newberg West – 8,858 kW; Newberg East – 7,741 kW; and Northern Groundwater – 10,885 kW.

(4) O&M costs based on 2012 JWC WTP budget with total cost of $0.39/CCF, including fixed and variable O&M costs. All costs in 2012 dollars. TBWSP O&M costs also include estimated pump-back costs. Total pump-back energy requirements were based on modeling conducted by MWH as part of the TBWSP. Requirements were assumed to be the average of the "moderate" and "conservative" scenarios. The moderate scenario assumed 50% of build-out demands and less aggressive pump-back targets, resulting in total annual energy usage of 5.5 M KW*hr. The conservative scenario assumed build-out demands and aggressive pump-back targets, resulting in total annual energy usage of 8.9 M kW*hr.

(5) Portland O&M costs based on additional treated supply of 30 mgd and total new capacity of 80 mgd. Treatment, power and chemical costs apply to treated supply to Hillsboro only.

(6) Portland wholesale cost assumed to be $0.951/CCF in 2012. This rate is TVWD's wholesale rate from Portland in FY2012-13. The rate was adjusted in future years to take into account changes in total demands on the Portland system due to projected decrease in Tigard usage and increases in JWC usage; 95% of Portland costs were assumed to be fixed.

(7) Northern Groundwater option also includes periodic renewal and replacement costs of $10 million in 2030 and $14 million in 2040.

4.0 ECONOMIC ASSUMPTIONS

A number of values were varied within the economic model. For general assumptions and variables, HDR researched historical indices to develop probability distributions for our projections. These parameters and the bases of their distributions are described in Table 2.

Table 2: Variables Within the Economic Evaluation of Water Supply Options

Variable	Distribution	Expected Values
Capital project cost	Triangular distribution based on level of overall cost risk, as described in TM 9B.	Varies by project risk level
Construction cost escalation	Construction Cost Index, Annual Averages (1930-2011); Engineering News Record.	4.76%
Variable O&M (power and chemicals) cost escalation	Average Retail Rate of Electricity for the Industrial Sector; Energy Information Administration.	5.23%
Fixed O&M cost escalation	General inflation (calculated average increase in gross domestic product, 1929-2011).	3.09%
Portland wholesale rate escalation	General inflation (calculated average increase in gross domestic product, 1929-2011).	3.09%

The probabilities of the various projections are correlated within the model.[1] For example, in any given simulation, if general inflation is predicted to be higher than average in a given year, then construction cost inflation would also be modeled higher than average.

5.0 CAPITAL COSTS

The expected values and timings for all capital and O&M costs are the values described in TMs 9A and 9C. Timing of the short dam raise was assumed to be the same as for the 40-foot dam raise in the Tualatin Basin Water Supply Project option, with construction completing in 2020 to allow the expanded Hagg Lake to fill by 2021.

As discussed in TM 9B, uncertainty was introduced into the capital project cost projections by assuming a range on probable costs for projects based on varying risk levels. Those uncertainties were modeled using triangular distribution functions, with upper and lower limits varying according to the overall cost risk level.

6.0 FINDINGS

The results of the economic evaluation are presented in three parts. First, there is a presentation of the NPV results *without* taking into account capital cost risk. Second, there is a presentation of the NPV results *with* consideration of capital cost risk. Third, there is a presentation of the Monte Carlo simulation results, which illustrates the range of potential outcomes for each supply option.

[1] Probability distribution functions and correlations were developed with @Risk for Excel. @Risk is an advanced statistical and risk analysis tool for spreadsheets.

The results presented in this section summarize the results of the analysis, *without taking into account cost risk*. Data are presented as overall costs in Table 3, with capital and O&M costs presented separately in Table 4 and Table 5, respectively. Included in each table are rankings for each option in order of least cost to highest cost. There are two sets of rankings, one based on the net present value of each source option, the other based on the undiscounted cost projections.

Table 3: Comparison of Projected Total Cash Flows

	Net Present Value Analysis				Undiscounted Analysis	
Scenario	Net Present Value	Rank	% from Lowest	Diff. from Lowest	Undiscounted Cash Flow	Rank
TBWSP	$1,085,000,000	4	27%	$231,000,000	$2,147,000,000	4
Willamette-Wilsonville	854,000,000	1	0%	0	1,803,000,000	1
Portland Supply	1,178,000,000	6	38%	324,000,000	2,693,000,000	6
Newberg West	1,050,000,000	3	23%	196,000,000	2,095,000,000	3
Newberg East	1,033,000,000	2	21%	179,000,000	2,050,000,000	2
Northern Groundwater	1,118,000,000	5	31%	264,000,000	2,429,000,000	5

Table 4: Comparison of Projected Cash Flows for Capital Costs

	Net Present Value Analysis				Undiscounted Analysis	
Scenario	Net Present Value	Rank	% from Lowest	Diff. from Lowest	Undiscounted Cash Flow	Rank
TBWSP	$945,000,000	6	36%	$248,000,000	$1,580,000,000	4
Willamette-Wilsonville	697,000,000	1	0%	0	1,157,000,000	1
Portland Supply	938,000,000	5	35%	241,000,000	1,751,000,000	6
Newberg West	891,000,000	3	28%	194,000,000	1,439,000,000	3
Newberg East	882,000,000	2	27%	185,000,000	1,430,000,000	2
Northern Groundwater	932,000,000	4	34%	235,000,000	1,664,000,000	5

Table 5: Comparison of Projected Cash Flows for O&M Costs

	Net Present Value Analysis				Undiscounted Analysis	
Scenario	Net Present Value	Rank	% from Lowest	Diff. from Lowest	Undiscounted Cash Flow	Rank
TBWSP	$139,000,000	1	0%	$0	$567,000,000	1
Willamette-Wilsonville	157,000,000	3	13%	18,000,000	646,000,000	3
Portland Supply	240,000,000	6	73%	101,000,000	942,000,000	6
Newberg West	159,000,000	4	14%	20,000,000	656,000,000	4
Newberg East	151,000,000	2	9%	12,000,000	621,000,000	2
Northern Groundwater	185,000,000	5	33%	46,000,000	765,000,000	5

As shown in Table 3, Willamette-Wilsonville is projected to be the least-cost option, and is approximately $179 million less expensive than the next least expensive option. The other two Willamette options, Newberg-West and East, are the next least expensive. The least-cost non-Willamette option was the TBWSP, with an expected NPV $231 million greater than for the Willamette-Wilsonville. The highest cost options were the Northern Groundwater and Portland supply options. Interestingly, the TBWSP has the highest NPV for capital cost, but the lowest for O&M.

7.0 RISK-ADJUSTED FINDINGS

The results presented in this section *include the effects of risk* probability on the capital costs. Similar to the previous section, results are presented by overall costs in Table 6, with capital costs presented separately in Table 7. O&M cost comparisons are the same as those presented above in Table 5. O&M costs are not affected by capital cost risk.

Table 6: Comparison of Projected Total Cash Flows (Risk-Adjusted)

	Net Present Value Analysis				Undiscounted Analysis	
Scenario	Net Present Value	Rank	% from Lowest	Diff. from Lowest	Undiscounted Cash Flow	Rank
TBWSP	$1,123,000,000	4	30%	$256,000,000	$2,207,000,000	4
Willamette-Wilsonville	867,000,000	1	0%	0	1,825,000,000	1
Portland Supply	1,218,000,000	6	40%	351,000,000	2,769,000,000	6
Newberg West	1,070,000,000	3	23%	203,000,000	2,129,000,000	3
Newberg East	1,054,000,000	2	22%	187,000,000	2,084,000,000	2
Northern Groundwater	1,159,000,000	5	34%	292,000,000	2,505,000,000	5

Table 7: Comparison of Projected Cash Flows for Capital Costs (Risk-Adjusted)

	Net Present Value Analysis				Undiscounted Analysis	
Scenario	Net Present Value	Rank	% from Lowest	Diff. from Lowest	Undiscounted Cash Flow	Rank
TBWSP	$984,000,000	6	39%	$274,000,000	$1,640,000,000	4
Willamette-Wilsonville	710,000,000	1	0%	0	1,179,000,000	1
Portland Supply	978,000,000	5	38%	268,000,000	1,827,000,000	6
Newberg West	911,000,000	3	28%	201,000,000	1,472,000,000	3
Newberg East	903,000,000	2	27%	193,000,000	1,464,000,000	2
Northern Groundwater	974,000,000	4	37%	264,000,000	1,741,000,000	5

The introduction of cost risk did not change the ranking of the options, as projects with higher capital costs also tended to have higher risk. However, risk did increase the projected NPV for all options as well as increasing the "spread" among the options. For example, the expected NPV of the Willamette-Wilsonville option is now $187 million less than the next least-cost option.

8.0 MONTE CARLO RESULTS

A Monte Carlo simulation was used to estimate the mean dispersion of the NPV for the supply options. Figure 1 (next page) shows the NPV rank frequency developed in the Monte Carlo Analyses. The x-axis represents the percentage of total iterations that the options were ranked in the order of least-cost to highest-cost options. For example, Figure 1 shows that the Willamette-Wilsonville option ranked as the least-cost option in 100% of the 20,000 iterations for this Monte Carlo simulation. The Portland option ranked as the highest-cost option in approximately 80% of the iterations.

The two tables that follow Figure 1 provide additional information to support Figure 1. Table 8 provides a summary of the number of times each scenario occurred at each ranking in the simulations. Table 9 provides the same information represented as a percent of the 20,000 iterations.

Figure 1: Rank Frequency by Source Option

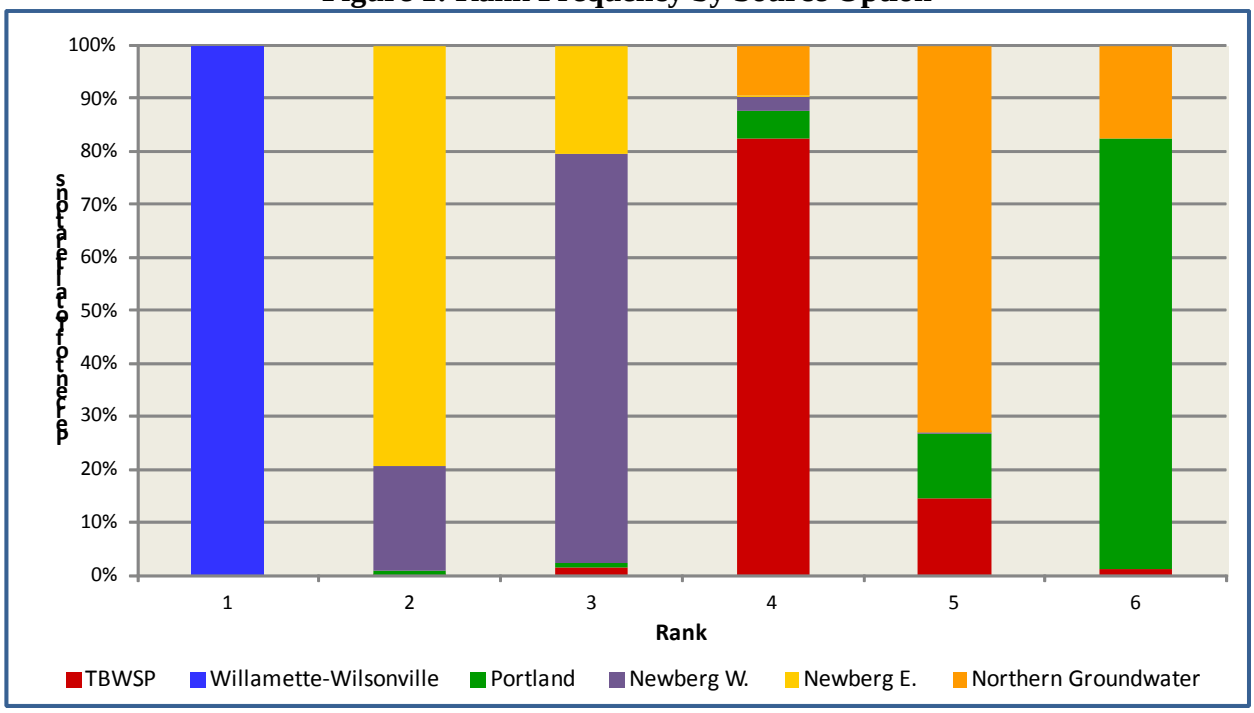


Table 8: Monte Carlo Analyses Rank Occurrence Results

Rank	TBWSP	Willamette-Wilsonville	Portland	Newberg W.	Newberg E.	Northern Groundwater
1		20,000				
2	22		150	3,982	15,846	
3	302		160	15,457	4,081	
4	16,494		1,028	514	72	1,892
5	2,923		2,443	47	1	14,586
6	259		16,219			3,522

Table 9: Monte Carlo Analyses Rank Frequency Results

Rank	TBWSP	Willamette-Wilsonville	Portland	Newberg W.	Newberg E.	Northern Groundwater
1		100.00%				
2	0.11%		0.75%	19.91%	79.23%	
3	1.51%		0.80%	77.29%	20.41%	
4	82.47%		5.14%	2.57%	0.36%	9.46%
5	14.62%		12.22%	0.24%	0.01%	72.93%
6	1.30%		81.10%			17.61%

Figure 2 provides probability distributions of total NPV project costs, with the NPV shown along the x-axis and the relative probability of that NPV shown along the y-axis.[2] As shown in the figure, the Willamette-Wilsonville option stands out as the least cost alternative, with less differentiation among the remaining supplies.

Figure 2: Comparison of NPV Ranges by Source Option

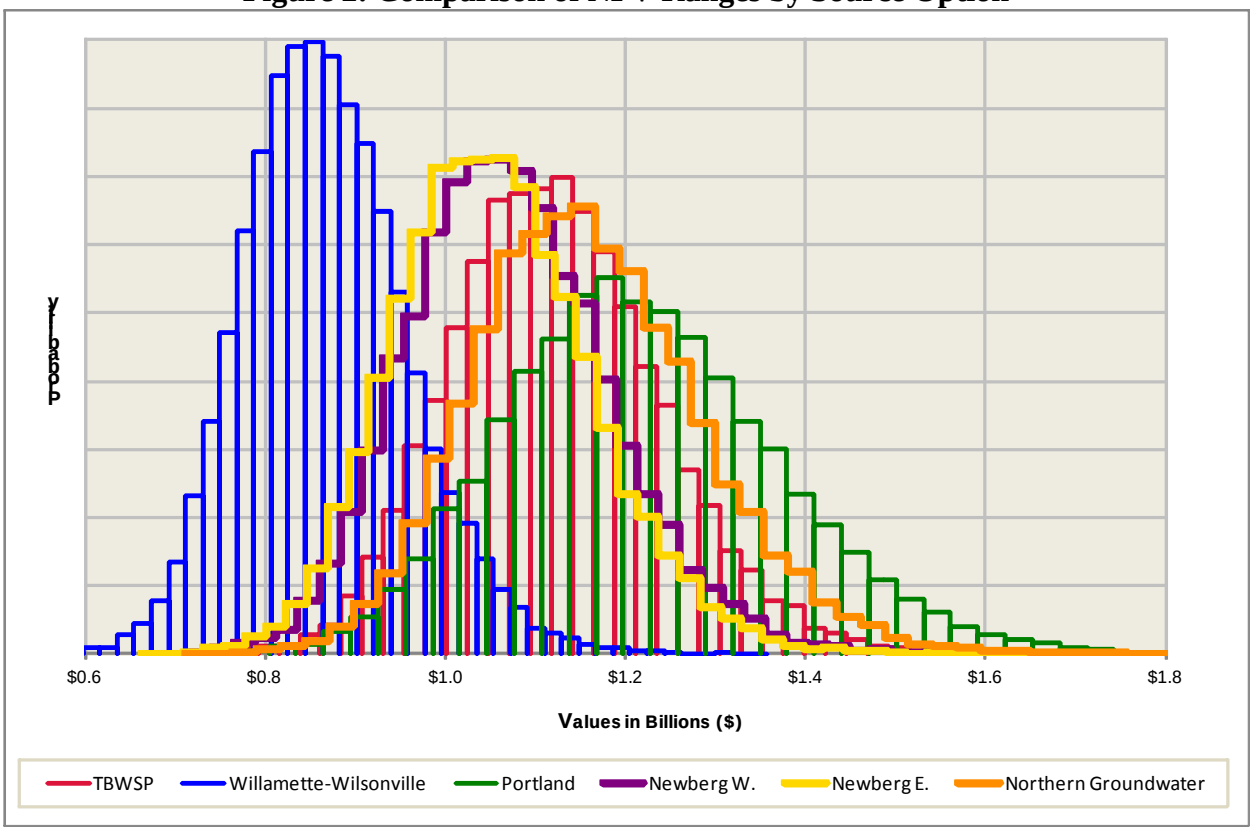
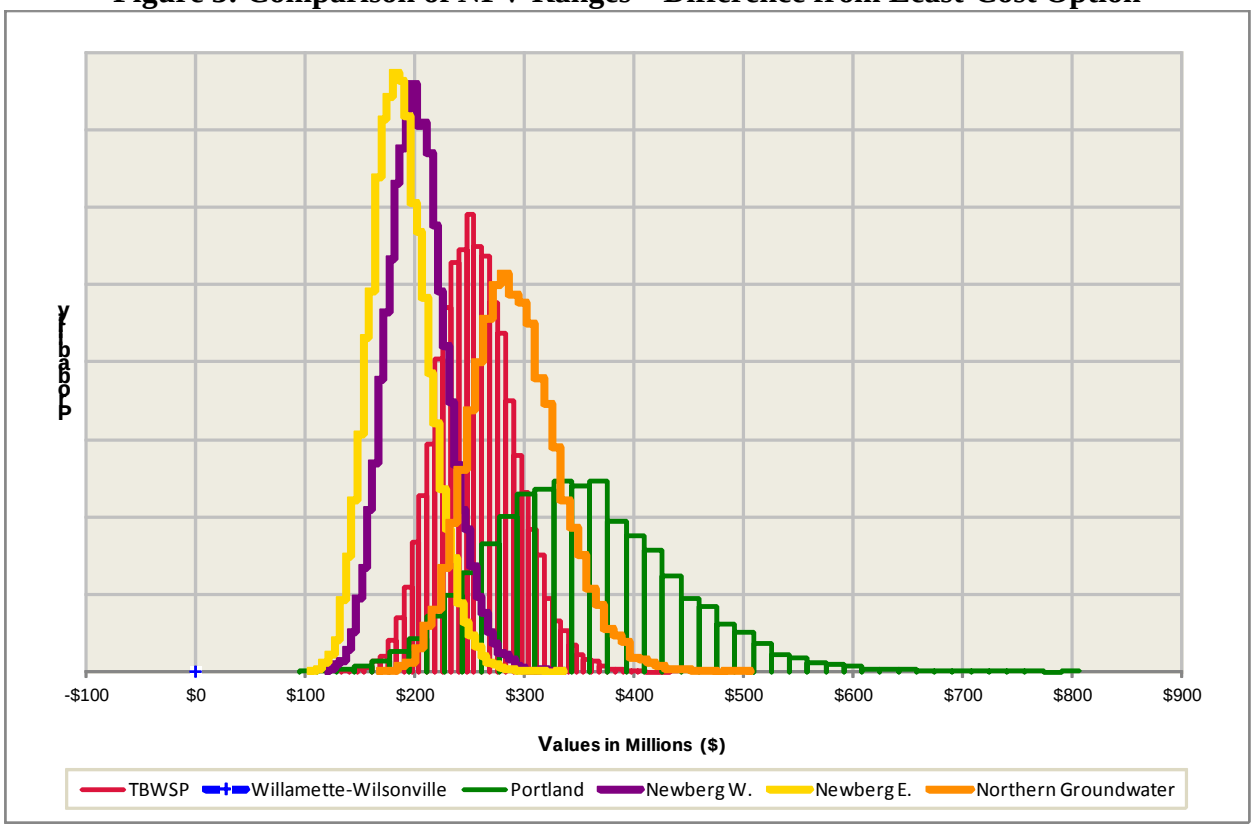


Figure 3 (next page) shows similar information, except that the x-axis is now the difference in projected NPV between each option at the least-cost option (in this case, the Willamette-Wilsonville supply). In this graph, the rankings of the alternatives are the same, but there is less spread in NPVs within each supply.

Figure 3 is more representative of the projected difference in costs among the options, whereas Figure 2 is more representative of the overall range of projected NPVs for each individual option. The reduced spread is because inflation factors vary among the individual Monte Carlo simulations, but affect all options. For example, if capital cost inflation is projected to be very high in one of the Monte Carlo iterations, the high cost projection would affect the projected capital costs of all options for that iteration.

[2] The area under the curve for each supply is equal to one.

Figure 3: Comparison of NPV Ranges – Difference from Least-Cost Option



9.0 SUMMARY

The above results present the projected NPVs for the six water supply options under consideration. The Willamette-Wilsonville option is projected as the least cost alternative. The rankings of the remaining options in order from least to highest cost are: Newberg East, Newberg West, TBWSP, Northern Groundwater, and Portland supply.