Applying Economic Analysis within WEAP: A Case Study for the Town of Sharon, Massachusetts

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Introduction

The WEAP model is set up to accept physical impact relationships and economic valuation of changes in those relationships. These features are being used to estimate potential values for changes in the ecosystem from changes in water management in an application developed for the Town of Sharon, Massachusetts.

Sharon was chosen because its issues are representative of some of the challenges other municipalities face and because the Town agreed to cooperate in a case study. The purpose of the case study is to illustrate how WEAP can be applied to a community, possible data sources for an application, and how the existing and new features of WEAP can be used for holist cost benefit analysis.

In this report, the new version of WEAP is applied to several, at times hypothetical, water resources planning issues in the Town of Sharon Because the examples are illustrative, they do not fully represent the conditions or issues in Sharon. Some of the data values are based upon engineering judgment. The examples do, however, provide guidance on the use of the WEAP model.

The examples, called Scenarios in WEAP parlance, include:

1. Impacts on water supply, runoff and wastewater from proposed high density developments and continued commercial and residential growth.
2. Possible use of emergency water supply from the Massachusetts Water Resources Authority.
3. The use of stormwater harvesting to facilitate groundwater recharge into the aquifer used for water supply.
4. Replacing the Cedar Swamp drainage ditch by a culvert to restore the more natural ground water elevations

The valuation is being assessed in two ways. These two approaches recognize an important aspect of environmental valuation—there is substantial uncertainty about (1) the physical pathway relationships between changes in water quantity, quality and aquatic ecosystem impacts and (2) in the relationship between ecosystem changes and economic valuation.

- The first approach is to apply values from the economic literature to the indicators of ecosystem changes estimated by the WEAP model (i.e. stream flow/stage, groundwater elevation, and reservoir storage/elevation). These were obtained through a search of the ecosystem service valuation literature. For this approach, we focused primarily on studies located in the Eastern United States and Massachusetts. Of particular relevance was a study commissioned by the Massachusetts Audubon Society.[1] This has a set of values specific to the Massachusetts region for a wide range of land uses, including wetland habitat. A study by Fredericks, et al. (1996) was our primary source for values of instream flow for the Eastern United States and, more specifically, New England. We supplemented this information through a review of a wide range of valuation studies that have been applied to a model of ecosystem benefits of water conservation in California.[2] While the California values will not be directly applicable, the study developed an environmental benefits estimation model that will be a useful template for determining how values appropriate to Massachusetts might be applied.

- The second approach is to estimate a set of threshold values which represent break-even or pivot points at which the environmental benefits could become determinative in the choice of outcomes. In other words, the model will estimate how much the environmental values would have to be to change the preferred outcome. In this way, the importance of the valuation becomes transparent to the stakeholders. This valuation can be used in one of two ways. The first is as a discussion point as to whether the environmental benefits are likely to be larger or smaller than the threshold estimated by WEAP. The second is to identify whether further work is required to better define and estimate an ecosystem benefit because it may be pivotal in a water management decision.

To address uncertainty in developing these estimates, the modeling team is evaluating different scenarios that reflect the range of parameter estimates, for both the physical relationships and the economic valuations. These ranges of uncertainty will be incorporated with the ranges of uncertainty about other key parameter estimates, such as demand forecasts and operational costs. The second approach will be used to assess the importance of refining estimates developed from the first approach, i.e., identifying the value of added information for the problem.

The details of the analysis are discussed in the sections that follow.

Sharon Water System Revenues

Three sources of water system revenues were defined for this study: (1) revenue from the sale of water; (2) annually recurring non-rate revenue; and (3) revenue from system connection fees. Water sales are Sharon’s primary source of water system funding, accounting for approximately 91% of system revenues over the period FY 1999-2006. Revenue from system connection fees is an important source of funding for capital improvement projects needed to serve new connections.

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[1] Found at www.massaudubon.org/losingground.

[2] Found at http://www.cuwcc.com/technical/action.lasso?-database=cuwcc_catalog&-layout=CDML&-response=detailed_results.html&-recordID=34196&-search.

We modeled water sales revenue using Sharon's current rate structure, which became effective May 1, 2007. Sharon employs an increasing-block rate schedule, as shown in Figure 1. The rate blocks are based on biannual reading of customer meters. Residential rates apply to single-family and high-density residential accounts while the "Other" rates apply to commercial accounts. We used these two rate schedules in the WEAP model to calculate annual water sales revenue from the residential, high-density, and commercial demand categories. Irrigation-only accounts, which comprise an insignificant share of total demand, are not represented as a separate demand category in the WEAP model. Thus, we did not incorporate the irrigation-only rates into the model.

WATER RATES
(PER 1,000 GALLONS)
Effective May 1, 2007

	Residential*	Other**	Irrigation Only
0-15,000	3.00	2.60	7.00
	(30.00 base fee)	(39.00 base fee)	(75.00 base fee)
15,000-30,000	3.50	3.00	7.00
30,000-45,000	4.50	3.40	7.00
Over 45,000	10.00	3.90	7.00

*30.00 base fee applies only to those customers using 15,000 or less per billing period.

**agriculture, commercial, and industrial uses

Figure 1. Town of Sharon Current Water Rates

Annually recurring non-rate revenue includes revenue from various fees, liens, interest, and other water income. Revenue from these sources averaged $145,000 per year over the period FY 1999-2006. We represented this source of revenue in WEAP as a fixed annual amount indexed to inflation. The model defines a base FY 2006 value of $145,000 and then applies a 3% annual inflation adjustment to forecast future annually recurring non-rate revenue over the simulation period.

Annual revenue from system connections depends on the number of connections occurring in a year and the fees paid per connection. Connection fees are approximately $2,000 per single-family residential connection and $1,000 per high-density dwelling unit. We use these unit values, indexed to a 3% inflation factor, along with a schedule of annual system connections, to calculate yearly system connection fee revenue over the simulation period. For simplicity, the model assumes connection revenue is collected in the year the connection is made.

Water System Costs

Five types of water system costs were defined for this study: (1) annual fixed operating costs; (2) annual variable pumping costs; (3) planned capital replacement and improvement costs; (4) MWRA connection costs; and (5) stormwater harvesting costs.

Annual fixed operating costs consist of water department staffing costs plus O&M costs that do not vary with the level of water demand. We estimated these costs using water department budget data provided by town of Sharon. Staffing costs for FY 2007 and FY2008 were taken from the water department's current staffing budget (Water Personnel Budget FY08 v4.xls). We applied town of Sharon's 3% cost of living adjustment (COLA) factor to the FY 2008 staffing budget to forecast water department staffing costs beyond FY 2008.

We derived annual fixed O&M costs by subtracting annual staffing costs and variable pumping costs (described below) from the annual operating budget. The derivation is shown in Table 1. We applied a 3% inflation adjustment factor to forecast annual O&M over the simulation period.

Table 1. Derivation of Annual Fixed O&M

FY 2007 Operating Budget[3]	$1,300,000
Less:	
Staffing Budget	($833,000)
Variable Pumping Costs	($107,971)
Net Operating Budget	$359,029

We separated annual variable pumping costs from other annual O&M so that town of Sharon could use WEAP to simulate system energy costs under alternative energy price and climate scenarios. Using 2006 pumping and energy records provided by town of Sharon, we regressed daily energy consumption against volume of water pumped to estimate the energy required to pump a thousand gallons at each well site. Results are shown in Table 2. The WEAP model uses the energy requirements shown in the middle column of Table 2 along with an energy price forecast to calculate energy costs by well site over the simulation period.

Table 2. Energy Cost by Well Site

WELL #	KWh/Thou Gal.[4]	Cost/Thou. Gal.[5]
2	2.434	$0.37
3	1.894	$0.28
4	1.322	$0.20
5	1.320	$0.20
6	1.319	$0.20
7	1.171	$0.18

[3] The source of the estimate for current annual operating budget is Hooper, Eric R., "Proposed Schedule of FY '08 Water Department Capital Projects." Memorandum to Board of Selectmen, William Heitin, Chair, Revised May 14, 2007.

[4] Calculated from daily pumping and energy consumption data by well for the period Jan 1, 2006 to Dec 31, 2006.

[5] Based on town of Sharon's average electricity cost of $0.15/KWh.

Annual capital replacement and improvement costs were taken directly from the water department's ten-year capital projects schedule.[6] Table 3 provides a summary of proposed annual capital expenditures through FY 2014. The water department describes projects scheduled beyond FY 2008 as tentative and notes that funding these projects may require rate increases and some amount of borrowing. Some of the anticipated capital expenditures relate to proposed high-density development and will be partially funded through connection fees.

[6] Hooper, Eric R., "Proposed Schedule of FY '08 Water Department Capital Projects." Memorandum to Board of Selectmen, William Heitin, Chair, Revised May 14, 2007.

Table 3. Proposed Capital Projects Schedule

Year	Project		Cost
FY07	Preferred Source	$	100,000.00
	Mansfield St. Replacement	$	350,000.00
	Radio Read	$	150,000.00
	Fe/Mn Treat. Const.	$	150,000.00
	Leak Det/Conserv/Consult	$	200,000.00
	Total FY07	$	950,000.00
FY07	Preferred Source	$	75,000.00
	Radio Read	$	150,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Total FY08	$	300,000.00
FY09	Preferred Source	$	75,000.00
	Radio Read	$	150,000.00
	Cast Iron Repl	$	250,000.00
	Fe/Mn Treat. Const.	$	750,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Total FY09	$	1,300,000.00
FY10	Preferred Source	$	75,000.00
	Radio Read	$	150,000.00
	Cast Iron Repl	$	250,000.00
	Fe/Mn Treat. Const.	$	750,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Total FY10	$	1,300,000.00
FY11	Preferred Source	$	75,000.00
	Radio Read	$	150,000.00
	Cast Iron Repl	$	250,000.00
	Pine Street Loop	$	250,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Total FY11	$	800,000.00
FY12	Preferred Source	$	75,000.00
	Cast Iron Repl	$	250,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Eisenhower, Hampton, Capen Hill, Mass Ave., Pond	$	1,841,000.00
	Total FY12	$	2,241,000.00
FY13	Preferred Source	$	75,000.00
	Cast Iron Repl	$	250,000.00
	Leak Det/Conserv/Consult	$	75,000.00
	Mountain Street, Pump inter-system valve, Storage Tank	$	3,180,000.00
	Total FY13	$	3,580,000.00
FY14	Preferred Source	$	250,000.00
	Cast Iron Repl	$	250,000.00
	Leak Det/Conserv/Consult	$	75,000.00
		$	575,000.00

Other capital and operating costs of interest to the Town of Sharon include costs to connect Sharon to the MWRA system and costs to implement a stormwater harvesting system. The research team is continuing to study these costs and intends to include them in future analyses.

Water System Financial Simulation

Calculating the financial performance of Sharon's water system involves several steps. First, WEAP is run to generate annual system revenues and costs for the reference scenario. Next it is run for each development scenario (described above). Resulting annual revenues and costs, along with the Water Department's Water Revenue Surplus Account balance at the start of FY 2007, are then used to calculate the Water Department's end-of-year cash balance for each year in the simulation. An analysis of end-of-year cash balances is then conducted to determine: (1) the adequacy of current rates and connection fees to fund operating costs and proposed capital projects under each scenario; (2) possible uses of debt financing to smooth annual cash flow and spread capital project costs more evenly across project beneficiaries; and (3) impact of high-density development and other sources of demand growth on system costs, revenues, and water rates.

Valuation of Changes to Local Stream flow

Alternative water system development scenarios will have different impacts on local stream flow. WEAP is used to evaluate these impacts in two ways. In the first approach, WEAP is used to characterize the physical changes in stream flow under different development conditions. An unimpaired stream flow baseline condition is first established by running WEAP in the absence of system demands and pumping. Next, WEAP is run under the reference scenario, which represents the current level of water system development. Results under the two conditions are then compared to determine the extent to which current levels of development have impaired local stream flow. WEAP is then run under each development scenario and resulting stream flows are compared to the baseline and reference conditions to determine how additional system development will physically alter local stream flow. Based on the calculated streamflow impacts, projects to mitigate these impacts can be defined and simulated. WEAP can then be run to calculate the present value cost to construct and operate these projects. This cost then constitutes the threshold value environmental benefits would need to exceed in order to justify the mitigation expense.

In the second approach, the *in situ* economic value of local stream flow is calculated directly using WEAP by multiplying the annual volume of flow by the instream economic value per unit of flow. This is done for each scenario. The difference in value between the baseline condition and reference scenario (assuming the reference scenario results in lower flows) represents the opportunity cost in terms of lost ecosystem and recreational services of current extractive uses of water. The difference in value between the reference scenario and future development scenarios represents an opportunity cost to the community of additional development of the local water resource.

To implement the second approach, a literature search was conducted to elicit instream water values for the Eastern United States. The literature search identified only two studies directly applicable to the Eastern United States or New England. Most previous studies of instream flow values have focused on rivers located in the Western United States and results were not deemed transferable due to significant differences in hydrodynamics, climate, water scarcity, and extractive uses. The search did identify one study (Frederick, et al., 1996) that reported instream flow values for various regions of the United States, including the East and New England. These values were subsequently used by Brown (2004) to estimate the marginal value of instream flow from national forests located in New England. Table 4 presents the range of instream flow values used to simulate *in situ* economic value of local stream flow. The last column of the table refers to the number of studies the estimates are based on. The data in the table are from Frederick, et al. (1996), updated to 2006 dollars, and represent the value of instream flow for recreation and fish and wildlife habitat.

Table 4. Economic Values of Instream flow

Region	Minimum ($/AF)	Median ($/AF)	Maximum ($/AF)	Number of Estimates
Eastern U.S.	$0	$5	$657	89
New England	$0	$5	$16	6

Source: Frederick, K.D., VandenBerg, T., & Hanson, J. 1996. *Economic Values of Freshwater in the United States*, Discussion Paper 97-03. Washington, D.C.: Resources for the Future.

Valuation of Cedar Swamp Acreage

Sharon's Atlantic White Cedar Swamp west of Lake Massapoag covers an area of 200 plus acres.[7] According to Buermann and Towner the swamp collects and purifies rainwater, which then seeps into the underlying aquifer and flows out in all directions, feeding the Canoe River, Beaver Brook and Billings Brook aquifers, as well as the springs that feed Lake Massapoag.[8]

The health of Cedar Swamp is primarily impacted by a drainage ditch that artificially lowers its water level. The ditch was constructed to prevent basement flooding during storms in a nearby housing subdivision. The ditch also keeps ground water elevations sufficiently below the septic systems so they can function. Some within the community believe groundwater extraction also is contributing to the drying out of the swamp. Further drying out of the peat underlying the swamp could reduce the swamp's capacity to filter and purify water and thus may have deleterious impacts on the town's water quality. Loss of the swamp would also cause the community to lose an important ecological and recreational resource.

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[7] Town of Sharon Water Department reports that the swamp covers about 211 acres. An article printed in the Sharon Friends of Conservation estimates the swamp is 600 or more acres.

[8] Buermann K and C. Towner, "Endangered: Sharon's Atlantic White Cedar Swamp," Sharon Friends of Conservation. Download available at http://www.sharonfoc.org/interest/swamp.html

To help restore the health of the swamp, the approximately 100 homes in the subdivision would have to have their wastewater differently managed. An example of a possible alternative is installing a sewer network in the subdivision, treating the wastewater with a package wastewater treatment plant, and pumping the effluent for use as irrigation and groundwater recharge at a nearby farm.

The estimated wastewater generation from the assumed 3 bedroom households is approximately 100 gallons per day per room or 300 gpd. Assuming a 20 percent consumption rate, the wastewater generation for the 100 households would be 24,000 gallons per day.

We estimate that moving these home off of septic and replacing the ditch running through the swamp with a culvert would require a capital investment of about $1.2 million and O&M costs of about $80,000/year. The annualized total cost of the conversion project is about $130,000/year. This should be viewed as a preliminary first-order cost approximation and we present it only to illustrate the calculation of possible costs and benefits associated with preserving Cedar Swamp.

Valuing the preservation of Cedar Swamp is difficult. Wetlands provide a range of economically important ecological services. The value of these services, however, is highly dependent on the type of wetland as well as its geographic location and extent. Thus, it is difficult to generalize. We therefore provide a range of possible values based on estimates culled from the literature.

Several recent studies have calculated the economic value of wetlands. Some of these studies address specific geographies and types of wetlands, while others are more global. Two recent studies have valued wetland acreage in Massachusetts. Audubon (2003) commissioned a benefits transfer study conducted by University of Vermont economists. This study estimated that the value of ecological services provided by wetlands in Massachusetts approximately ranges between $8,500 and $35,000 per acre per year, with an average value of about $17,000 per acre per year (2006 dollars). World Wild Life Fund (2004) estimated the value of wetlands supported by the Charles River, which account for 75% of all the wetlands in Boston's major watershed, to average about $12,300 per acre per year. World Wild Life Fund (2004) also reported average values for different ecological services for all wetland types and geographies. Average values for water filtering, water supply, amenity recreation, and biodiversity, arguably all services provided by Cedar Swamp, sum to approximately $1,200/acre/year (2006 dollars). World Wild Life Fund (2004) also reported average values for specific types of wetlands in particular regions of the world. For Freshwater Woodland wetlands, such as Cedar Swamp, located in North America, it reported an average value of just $9/acre/year, considerably lower than the other estimates reviewed for this study.

We use the above value estimates to generate an annual value range for Cedar Swamp. Our low value estimate uses the average value for North American Freshwater Woodland wetlands. This is $9/acre/year. Our medium value estimate uses the average value for water filtering, water supply, amenity recreation, and biodiversity reported by World

Wild Life Fund (2004). This is $1,200/acre/year. Our high value estimate uses the lower-end of the range of values for Massachusetts wetland acreage reported in Audubon (2003). This value is $8,500/acre/year. Our decision to use the lower-end of the Audubon range is informed by the World Wildlife Fund (2004) findings of relative value of wetlands by type of wetland.

We apply these values to lower- and upper-bound estimates of Cedar Swamp acreage. The lower-bound estimate is 211 acres, as reported by Sharon's Water Department. The upper-bound estimate is 600 acres, as reported by Buermann and Towner. The valuation range is shown in Table 5.

Table 5. Benefits of Cedar Swamp Ecosystem Services ($/Yr; 2006 dollars)

	Cedar Swamp Area	
Value/Acre/Year	211 acres	600 acres
Low	$1,899	$5,400
Medium	$253,200	$720,000
High	$1,793,500	$5,100,000

Values in Table 5 can be directly compared to the annualized cost of $130,000/year for the septic conversion project. Such a comparison indicates the project would generate positive net benefits if Cedar Swamp acreage is valued using either the medium or high value/acre/year estimates, but would generate negative net benefits if the swamp is valued using the low estimate. The size of the swamp area is not a determining factor in whether net benefits are positive or negative.

The initial valuation of preserving Cedar Swamp does not require the use of WEAP. WEAP, however, can be used in subsequent analyses of impacts. For example, WEAP can be used to determine the impact of the septic conversion project on water rates, and how these impacts would be distributed across different demand categories. Moreover, if information on the physical pathways between swamp water levels and groundwater movement and extraction become available, WEAP could then be used to simulate how different levels of development and water pumping would affect the health of the swamp overtime.

Summary

WEAP is being used to evaluate direct financial impacts of water system expansion for the town of Sharon as well as to value the environmental consequences of this development. The financial impact analysis required specification of water system revenues and costs within WEAP. Three sources of water system revenue were defined for this study: (1) water sales revenue; (2) non-rate revenue; (3) and connection fee revenue. WEAP's internal structure was modified to allow direct representation of block water rate structures. This allowed us to fully represent town of Sharon's increasing-block rate structure within the WEAP modeling environment. We parameterized the revenue-side of the WEAP model using readily obtainable financial data from town of Sharon.

On the cost-side, five types of water system costs were defined for this study: (1) annual fixed operating costs; (2) annual variable pumping costs; (3) planned capital replacement and improvement costs; (4) MWRA connection costs; and (5) stormwater harvesting costs. Data to represent the latter two costs in WEAP are still underdevelopment. We parameterized the first three costs using data provided by town of Sharon. Variable operating costs were modeled separately from other annual costs so that WEAP could be used to trace through changes in demand and pumping to changes in system costs and rates.

WEAP can then be run for alternative development scenarios to evaluate (1) the adequacy of current rates and connection fees to fund operating costs and proposed capital projects under each scenario; (2) possible uses of debt financing to smooth annual cash flow and spread capital project costs more evenly across project beneficiaries; and (3) impact of high-density development and other sources of demand growth on system costs, revenues, and water rates.

A range of unit values for instream flow were culled from the literature and used to parameterize the WEAP model so that it could directly calculate the *in situ* economic value of local stream flow. The WEAP model can then be run for "with" and "without" development scenarios to determine the physical impacts to streamflow and associated opportunity costs in terms of forgone amenity recreation and fish and wildlife habitat. Alternatively, WEAP can be used to calculate the costs of projects that could physically mitigate streamflow impacts. Such mitigation costs can be interpreted as threshold values that instream flow benefits would need to exceed to make such mitigation economically viable.

Lastly, we evaluated the potential range of values associated with preservation of Cedar Swamp and first-order cost estimates associated with preservation. WEAP can then be used to determine the impact of the septic conversion project on water rates, and how these impacts would be distributed across different demand categories.