

PRIORITIZING AREAS FOR WATERSHED-BASED STORMWATER PLANNING

By

Amy L. Shallcross, PE, New Jersey Water Supply Authority, and
Mark Maimone, PE, DEE of Camp Dresser and McKee, Inc.

ABSTRACT

The Raritan Basin is a 1,100 square mile watershed containing 136 subwatersheds. Recently, stakeholders in the basin completed the Raritan Basin Watershed Management Plan. One major strategy of the plan for water resources protection is the development of watershed-based stormwater management plans. Once developed, these plans will become part of the area-wide water quality management (“208”) plans and enforceable by the State under State law. The first two steps of this strategy are to identify and prioritize subwatersheds where such stormwater management plans are most needed. With the watersheds ranked, the stakeholders can focus their efforts on developing the partnerships and funding sources necessary to develop the watershed-based stormwater management plans.

A basin-wide stormwater management committee was formed to evaluate the 136 subwatersheds. Committee members brainstormed the types of information that would be useful for evaluating the subwatersheds to determine which ones should be targeted first for watershed-based stormwater management plans. The criteria are both qualitative (e.g. subwatershed contains a trout production stream) and quantitative (e.g. subwatershed impervious cover). The criteria include information about population, land use, flooding, ground water, pollutant loads and natural resources. These criteria yielded a voluminous amount of useful information for evaluating the subwatersheds. For comparison purposes, the criteria were grouped into five categories: level of development, ground water, flooding, nonpoint source pollution contribution, and natural resource value.

To facilitate the comparison of the subwatersheds, CDM (Camp Dresser and McKee) assisted the Committee in the assessment process with the use of a decision support tool called EVAMIX. EVAMIX is a computerized representation of the decision making process that can evaluate mixed criteria: quantitative and qualitative. The evaluation has three components: objective, subjective, and a mathematical algorithm. The objective component of the evaluation is based on the data (facts). The subjective component is based weights assigned to each of the criteria. The weight is determined by the importance the Committee gives to the criterion. The mathematical algorithm performs pair-wise comparisons of the subwatersheds resulting in appraisal scores and ranks.

The analysis resulted in 14 subwatersheds to be targeted for the development of watershed-based stormwater management plans. For each watershed, stakeholders were asked to determine the level of interest at the local level and the potential for viable partnering in planning. Of those, a Section 319 non-point source grant proposal was successfully submitted for three subwatersheds located within the same HUC11 for the development of a watershed-based stormwater management plan.

BACKGROUND

The Raritan Basin Watershed Alliance (RBWA)¹, a partnership of stakeholders interested in protecting and preserving the water resources of the Raritan Basin, is facilitating the implementation of the Raritan Basin Watershed Management Plan². One high priority strategy of the plan, RB-S7:³ is the

¹ The RBWA is a voluntary affiliation of stakeholders, formed through the Raritan Basin Watershed Management Project, to coordinate watershed management activities in the Basin.

² http://raritanbasin.org/management_plan.htm.

³ <http://www.raritanbasin.org/RBWMP/Plan/Basin/RB-S7.pdf>

development and implementation of watershed-based stormwater management plans. The first two steps of this strategy are to identify and prioritize subwatersheds for the development of these plans. With the prioritized watersheds, the RBWA can focus their efforts on developing the partnerships necessary to develop watershed-based stormwater management plans.

METHODOLOGY

The basin wide stormwater management committee was formed to devise a methodology to evaluate the 136 HUC14⁴ subwatersheds of the Raritan Basin. For the first meeting of the committee, staff prepared a database of information about all of the HUC14s that might be useful for determining which subwatersheds should be targeted for (the first) stormwater management plans. Committee members were then asked to brainstorm additional information and criteria that could be used to evaluate the subwatersheds. To facilitate the comparison of the subwatersheds with the criteria, CDM assisted the committee through the assessment process with the use of a decision support tool called EVAMIX, a computerized representation of the decision-making process that can evaluate mixed criteria. The evaluation has three components: objective, subjective, and a mathematical algorithm. The objective component of the evaluation is based on the data and facts provided by the criteria. The subwatersheds are scored using the information for each criterion. The subjective component is based on weights assigned to each of the criteria. The weights are determined by the importance the committee gives to each criterion. The mathematical algorithm performs pair-wise comparisons of the subwatersheds resulting in appraisal scores and a ranking for each.

EVAMIX

EVAMIX is a matrix based, multiple criteria, decision support tool that has been applied in a variety of water resource planning applications, and is specifically designed to aid planners and engineers in the evaluation of alternative plans, sites, or technologies. Developed in the Netherlands in the 1980s, this tool capitalizes on concordance/discordance analysis (pair-wise comparisons) and a goals achievement matrix using both quantitative and qualitative criteria, regardless of the units of measure. The algorithm behind EVAMIX maintains the essential characteristics of the quantitative and qualitative criteria, performs pair-wise comparisons of the subwatersheds, and evaluates to a mathematically rigorous appraisal score for each subwatershed.

Figure 1 is a conceptual representation of how EVAMIX evaluates both quantitative (also called cardinal) and qualitative (also called ordinal) data. The data are first divided into the two categories (cardinal and ordinal), along with the weight associated with each criterion. Then, a dominance score is calculated for each subwatershed (“A” for cardinal data and “a” for ordinal data). These scores represent the degree to which subwatershed X dominates subwatershed Y and are calculated for all pairings of subwatersheds. For cardinal data, the dominance score (D_{XY}) for X over Y is higher if X is significantly better than Y, but would be low if the two subwatersheds had near equal values for that criterion. For ordinal criteria, only the fact that X is better than Y is recorded (d_{XY}) as the dominance score. Thus, EVAMIX treats qualitative or ordinal criteria correctly, by only recording a preference, not a degree of preference, for one over the other. The dominance scores (M_{XY}) for each pairing are calculated by weighting the individual’s dominance scores for each criterion (D_{XY} and d_{XY}). Then, a final appraisal score (S) is calculated and represents the overall worth of choosing that subwatershed over other subwatersheds, based on the criteria selected and the weights given each criterion. The appraisal score is used to calculate the rank or priority of each subwatershed from most favorable to least favorable for the development of a watershed-based stormwater management plan.

⁴ HUC14 stands for Hydrologic Unit Code. The number 14 indicates the general level of delineation. For instance, the Raritan Basin is a HUC8 – 02030105. The HUC14s of the Raritan Basin range in size from XX to YY acres.

THE CRITERIA

The criteria are both qualitative (subwatershed contains a trout production stream) and quantitative (subwatershed impervious cover). Table 1⁵ lists the criteria, which include information about population, land use, flooding, groundwater, pollutant loads and natural resources. Some criteria represent similar information. For instance, wetlands are expressed as total area in the subwatershed and percentage of the subwatershed area. The expression of the criteria makes a difference in the resulting ranking based on the goals of the assessment. The 29 criteria for 136 subwatersheds yielded a voluminous amount of useful information for evaluating the subwatersheds. These criteria were grouped into five categories for comparison purposes: level of development, groundwater, flooding, nonpoint source pollution contribution, and natural resource value.

SCENARIOS

The criteria weights represent the importance of the criteria to the decision makers. Different weighting schemes or scenarios will produce different rankings of the subwatersheds. Since weights represent the subjective opinions of the persons setting value to the criteria, not all scenarios will be favorable to all parties involved. Ten schemes, modified to seven, were used to rank the criteria. They are as follows:

- A. Equal Weights – All Criteria: All 29 criteria were given the same weight – group weights reflect the number of criteria in the group.
- B. Equal Weights – No Duplicate Criteria: Only one of all potentially duplicate criteria (such as population and population density) was used in the analysis – group weight reflects the number of criteria in the group.
- C. Increased Stress to Stressed Areas (Original): The evaluation is based on criteria that indicate potential stress to already stressed areas. This was a brainstormed (on the fly) scenario that the work group developed during a meeting.
- D. Increased Stress to Stressed Areas (Modified): Same as C with revisions to criteria weights based on discussions of the committee (not outcomes of EVAMIX).

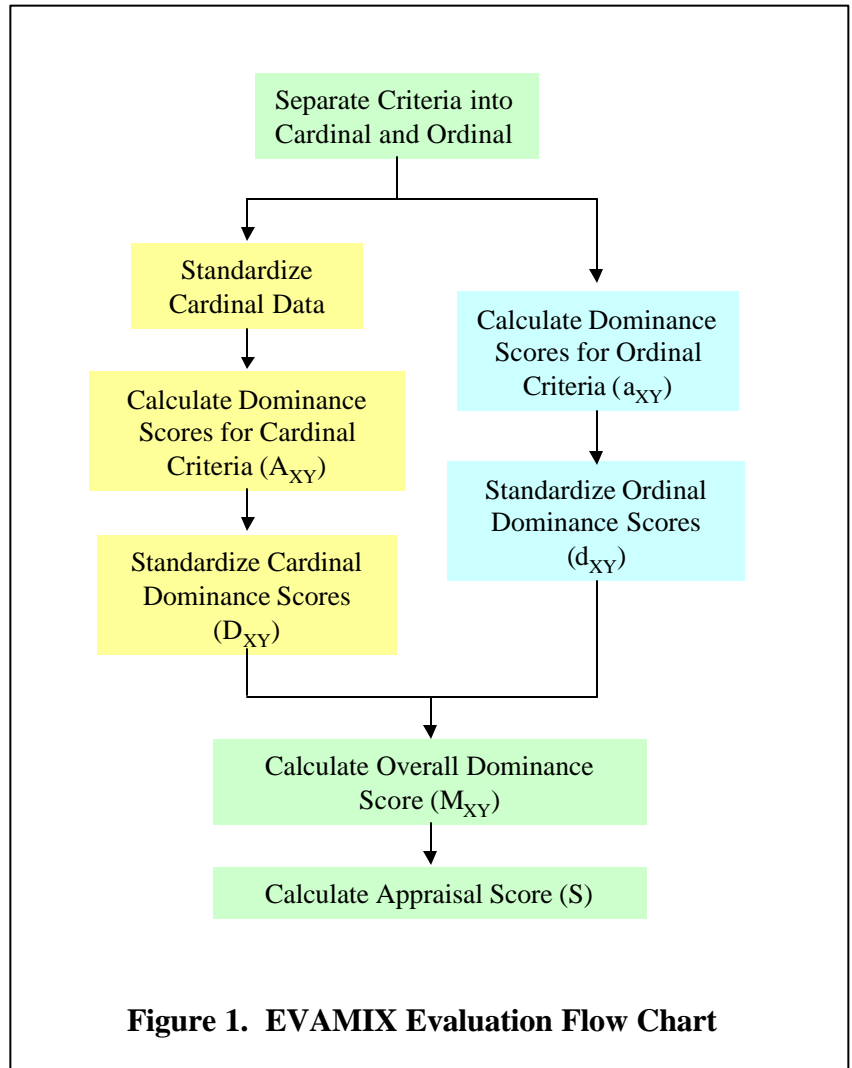


Figure 1. EVAMIX Evaluation Flow Chart

⁵ Appears on the last page of the paper.

- E. Increased Stress to Unstressed Areas (Original): The evaluation is based on criteria that indicate potential stress to unstressed, more pristine, areas. This was a brainstormed (on the fly) scenario that the work group developed during a meeting.
- F. Increased Stress to Unstressed Areas (Modified): Same as D with revisions to criteria weights based on discussion of the committee (not outcomes of EMAMIX).
- G. Development Potential: Criteria that reflect a significant potential for future development were used in this scenario. Criteria related to development indices given higher weights.
- H. Natural Resources Protection: Criteria that indicate the presence of natural resources were used in this scenario. Criteria that related to the presence/absence of a natural resource or the quantity of a resource were given greater weights.
- I. Nonpoint Source Pollution Potential: The evaluation is based on criteria that indicate a propensity for contributing to nonpoint source pollution. These criteria were given higher weights.
- J. Equal Group Weights – Minimum Criteria: This evaluation was based on the selection of the minimum amount of criteria to represent each group with the groups weighted equally.

Unless specifically noted, all group weights were assigned first, then, the weights for individual criteria were determined. Scenario A was eliminated because duplicate criteria would have twice the weight of other criteria. Scenarios C and E were eliminated because they were precursors to more refined scenarios.

The seven scenarios are also presented in Table 1⁶. For each cardinal criterion, in addition to a weight, a desired tendency (+N, -N) also was specified. For the criteria of impervious surface, larger values rank higher if the scenario is to target subwatersheds that are already stressed (+N); whereas, smaller values of impervious surface would rank higher if the scenario is to target unstressed watersheds (-N).

ASSESSMENT

With the seven scenarios evaluated, the committee had seven sets of ranked subwatersheds. For each scenario, the subwatersheds were sorted by rank from highest to lowest. The “top 10” subwatersheds were highlighted based on that sort. Then, those “top 10” for the scenario were reviewed for “top 10” scores in other scenarios. The fourteen subwatersheds with the most “top 10” ranks are those watersheds considered to have the highest priority for the development of watershed-based stormwater management plans. The basin wide stormwater management committee also realized that other non-tangible criteria also need consideration. Such criteria include the interest and motivation of municipalities within the subwatersheds, perception of stormwater as a problem, existence of hydrologic data, geographic diversity, linkages to regulatory objectives, and other issues.

Of the fourteen subwatersheds that were prioritized through this analysis (the “top 10” percent of subwatershed in the basin), five received attention from interested stakeholders. A 319 Nonpoint Source Pollution Abatement grant proposal, “Development of a regional stormwater management plan for Devil’s, Shallow, Cedar and Cranbury Brooks,” which included three of the “top 10” subwatersheds, was successfully submitted. The \$440,000 project area is located in a rapidly developing area with large areas of wetlands. In addition, two other 319-grant proposals for watershed-based stormwater management plans (for other highly ranked subwatersheds in individual scenarios) resulted from the analysis. These projects, which contain 5 and 2 subwatersheds, also obtained grants for projects totaling \$127,000 and \$70,000, respectively. The “Regional stormwater management plan for the Sourlands Mountains,” contains 5 subwatersheds, which are located in a sensitive headwaters area. The “Regional

⁶ Appears on the last page of the paper.

stormwater management plan for the Pleasant Run and Holland Brook watersheds” contains two subwatersheds, which are located in a rapidly developing community.

STAKEHOLDER REACTIONS

The basin wide stormwater management committee and other stakeholders were pleased with the methodology used to prioritize the subwatersheds. Many in the committee indicated that some of the value of the analysis was the process of defining the criteria, weighting the criteria, and selecting the scenarios. Through the negotiation of criteria and weights, stakeholders exchanged ideas and opinions, sometimes rather diverse, about where and why watershed-based stormwater management plans should be developed in the more immediate future. Another value of the analysis was that EVAMIX objectively evaluates both the qualitative and quantitative data in a structured and logical fashion.

CONCLUSIONS

Use of the EVAMIX method successfully allowed a committee of Raritan Basin stakeholders to establish priorities for the development of watershed-based stormwater management plans in a manner that recognized a value from prior work, a variety of scenarios that might instigate a desire for the development of such plans, and the need to provide justification to the State for investment of source grant funds. The successful grant proposals for high priority subwatersheds can be directly attributed to this process, both through the process of the evaluation and the discussion of the committee about the criteria most important to them for the development of watershed-based stormwater management plans. The EVAMIX process was useful in organizing the voluminous data in a format amenable to the decision making process, stimulated thought and discussion about the reasons for deciding to pursue a watershed-based stormwater management plan, and provided an open and reproducible decision mechanism.

REFERENCES

Maimone, Mark and Christopher S. Crockett, EVAMIX: A Decision Support Tool Proves the Key to Source Water Assessment on the Schuylkill River, Conference Proceedings of the Source Water Assessment Symposium, AWWA, Albuquerque, NM, January 2003.

New Jersey Water Supply Authority, Raritan Basin Watershed Management Project Technical Reports, http://www.raritanbasin.org/technical_reports.htm.

Table 1 follows on the next page.

Table 1: EVAMIX Criteria and Scenarios for Prioritizing Subwatershed for Watershed-based Stormwater Management Plans

GW = Group Weight, TC = Type of Criteria (+N, -N, Q), IW = Individual Weight, +N means that a larger value indicates a better target area, -N means that a smaller value indicates a better target area, Q is a qualitative Criterion (presence/absence) (

SCENARIO		B: Equal Weight No Duplicates			D: Modified Increased Stress to Stressed Areas			F: Modified Increased Stress to Unstressed Areas			G: Development Potential			H: Natural Resource Protection			I: Most Potential Pollutant Load			J: Equal Group Weight Minimum Criteria										
Grouping	Criteria	GW	TC	IW	GW	TC	IW	GW	TC	IW	GW	TC	IW	GW	TC	IW	GW	TC	IW	GW	TC	IW								
Level of Development	Impervious Surface	25%	+N	4.2%	40%	+N	5.0%	25%	-N	3.0%	50%			30%	-N	7.5%	35%	+N	11.7%	20%	+N	10%								
	Historic Riparian Area Loss		+N	4.2%		+N	5.0%		-N	3.0%		-N	12.5%																	
	Sewer Service Area		+N	4.2%		+N	5.0%		-N	3.0%		+N	12.5%					-N	7.5%											
	Percent Urban (1995)		+N	4.2%		+N	5.0%		-N	3.0%		-N	12.5%					+N	7.5%											
	2000 Population																													
	2020 Projected Growth																													
	2000 Population Density		+N	4.2%		+N	5.0%		-N	3.0%																				
2020 Growth Density	+N	4.2%	+N	15%	+N	10%	+N	12.5%	+N	7.5%	+N	11.7%	+N	10%																
Groundwater Impacts	Groundwater Recharge (MGD/sqmi)	8%	+N	4.2%	10%			15%	+N	7.5%	10%	+N	5.0%	10%	+N	10.0%	10%			20%										
	Recharge Loss MGD/Sqmi/yr Recharge Area (Sqmi)		+N	4.2%		+N	10%		-N	7.5%		-N	5.0%					-N	10.0%		-N	20%								
Flooding (Quantity)	FEMA-FIP Flood Damage Claims	8%	Q	4.2%	5%	Q	5.0%	10%	Q	10.0%	5%	Q	1.0%	5%			10%	Q	10.0%	20%										
	Flood Area (Percent of HUC)		+N	4.2%					+N	4.0%		+N	5.0%					+N	20%											
NPS Load Contribution (Quality)	Total Phosphorus Load (lb/day)	17%	+N	4.2%	35%	+N	8.8%	20%	-N	6.3%	15%	+N	3.8%	5%	-N	1.3%	35%	+N	8.8%	20%										
	TSS Load (lb/day)		+N	4.2%		+N	8.8%		-N	6.3%		+N	3.8%		-N	1.3%		+N	8.8%		+N	20%								
	Total Chloride Load (lb/day)		+N	4.2%		+N	8.8%		-N	6.3%		+N	3.8%		-N	1.3%		+N	8.8%											
	Total Organic Carbon Load (lb/day)		+N	4.2%		+N	8.8%		-N	6.3%		+N	3.8%		-N	1.3%		+N	8.8%											
Natural Resource Value	Critical Habitat (Acres)	42%			10%			30%			20%			50%	+N	6.3%	10%			20%										
	Critical Habitat (Percent of HUC)		+N	4.2%		-N	3.0%		+N	10.0%		+N	6.7%																	
	Wetland Area (acres)																	+N	6.3%											
	Wetlands (Percent of HUC)		+N	4.2%		-N	3.0%		+N	3.3%																	+N	10%		
	Source Water Area		Q	4.2%		Q	3.0%		Q	3.3%																	Q	5.0%		
	Stream thru dense forest		Q	4.2%		Q	3.0%		Q	3.3%																				
	Trout Production Stream		Q	4.2%																										
	Trout Maintenance		Q	4.2%																										
	Category 1 Waters		Q	4.2%																										
	USEPA Priority Wetlands		Q	4.2%																										
	Most upstream HUC 14 (s)		Q	4.2%																										
	Ponds, Reservoirs, Lakes		Q	4.2%		Q	3.0%		Q	3.3%																				
		1	24	1	1	17	1	1	20	1	1	15	1	1	18	1	1	11	1	1	7	1								