WPDRD Master Plan Water Quality Problem Score Method Revision

City of Austin
Watershed Protection and Development Review Department
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Abstract

Water quality problem score calculation methods for inclusion in the Watershed Protection and Development Review Department master plan process were updated based on staff experience as part of the on-going master planning process. The revised problem score methods are more transparent and targeted to specific solution opportunities. A method for a combined problem score that can be used in combination with flooding and erosion problem scores in the mission integration process is proposed. Individual problem scores will be used for prioritization purposes for the set of feasible and existing solution options. The Environmental Integrity Index score will remain the overall indicator of total environmental integrity.

Introduction

The City of Austin Watershed Protection and Development Review Department (WPDRD) watershed master plan (COA 2001) uses technical assessments to compile information on and prioritize the watershed problems for the three missions of the WPDRD: flooding, erosion and water quality. The WPDRD master plan includes solution development and implementation phases through a mission integration process whereby problem areas are identified, ranked and solutions implemented through various methods including capital improvement plan (CIP) projects. Flood and erosion problem scores are reported on a 0-100 (good to bad) scale.

For the water quality mission, the technical assessment is completed through the Environmental Integrity Index (EII) field sampling program (COA 1997). The EII assesses overall watershed quality using six sub-indices (contact recreation, water quality, aesthetics/non-contact recreation, aquatic life, sediment quality, habitat quality), each calculated by different components measured during field observations and reported on a 0-100 scale (bad to good). EII scores are observed, calculated and stored by the staff of the Water Resource Evaluation (WRE) section of the WPDRD.

EII scores are translated to problem scores which are used in the CIP selection process. Previous water quality problem scores were calculated by the formula:

$$\text{Problem Score} = \sum_{i=1}^{n} [(W_{cur}*RV_{cur}*CPS*) + (W_{fut}*RV_{fut}*FPS)]$$

where n = number of receiving waters
W_{cur} = Weight assigned to Current problems
RV_{cur} = Resource Value for Current Conditions
CPS = Current Problem Severity Score
W_{fut} = Weight assigned to Future problems
RV_{fut} = Resource Value for Future Conditions
FPS = Future Problem Severity Score

The 2001 master plan water quality problem score calculation method has been characterized as overly complex, lacking transparency and strongly influenced by the various weighting factors. Problem severity was based on a "goal gap." Current and future scores were combined, although candidate solutions (e.g., capital projects, regulations, and programs usually require either the current or the future score but not both. The model for predicting future scores is not be calibrated to current conditions, is no longer supported, and was based on outdated land cover data. The previous current problem score method, based on the average of all six EII sub-indices (themselves based on 28 inputs), tends to dilute scores resulting in an indirect linkage between problems and specific solutions.

Based on staff experience, the method for calculating the water quality problem score has been revised and updated generally following the methods used by the WRE to address unacceptable decreases in EII scores according to the departmental action plan (COA 2003, COA 2005, COA 2007). The proposed revisions will better reflect actual environmental conditions: the worst problems will have the highest scores, will use the most indicative factors, and will enable more specific evaluation of post-implementation solution effectiveness.

The EII score will continue to be the overall measure of the environmental integrity of a given sampling reach. Individual, solution-specific problem scores will be used to assess and prioritize reaches for a set of different feasible solution options including structural BMP, regulatory, and programmatic approaches.

Methods

Water quality problem scores will be calculated using components on the EII on a watershed reach basis. Individual problem scores will be ranked and prioritized for distribution to solution implementers. To aid in interpretation, problem scores will be scaled 0-100. An overall water quality CIP problem score on a 0-100 scale will be generated for use in the mission integration process with flood and erosion problem scores. The EII score, however, will remain the overall indicator of environmental integrity.

There are currently 123 EII reaches in 50 different watersheds monitored by the WRE surface water team (figure 1), selected on the basis of similar hydrology, geomorphology, land use, point sources and predicted future impacts. Note that the narrative scales of the EII and the problem score are reversed such that a larger EII score reflects a more positive condition while a larger problem score reflects a more negative condition.

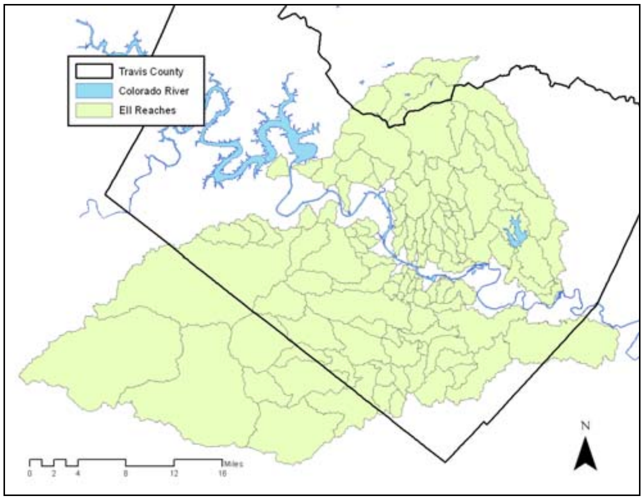

Figure 1. EII reaches.

Field staff recognizes the critical dependency of flow regime on aquatic life community integrity. Without base flow or with an extremely "flashy" flow regime, aquatic life will be negatively impacted. In addition to the EII, flow information will be included in the water quality problem score. Soil and Water Assessment Tool (SWAT) models, calibrated for gauged watersheds and extended to all monitored reaches by Water Quality Monitoring team (WQM) staff, will be used to predict reach flows. Future flow conditions will be predicted by replacing current land use with predicted future land use provided by Planning and GIS team staff.

Nine specific current problems and a future problem score that may be assessed through existing EII components or SWAT modeled hydrology were identified (table 1). The calculation method for each component is detailed. EII scores are scaled 0-100 (bad to good) and are thus frequently "inverted" (subtracted from 100) to yield a problem score that are scaled 100-0 (bad to good). Problem scores may be less than zero for some problems because the subtraction of two unrelated EII components. Negative problems should be considered as low priority and set to zero in any score combination method. Problems should be scaled (0-100) for any combinatory method to equally weight component problems.

Table 1. Water quality problem scores and solutions.

Problem to Fix	**Solution Type Examples**
Toxins in sediment	CIP, regulation (i.e., pavement sealant ban)
Litter	Programs (Keep Austin Beautiful, creek cleanups)
Bacteria from animals	Programs (Scoop the Poop)
Sewage	CIP (Austin Clean Water Program)
Nutrients (non-sewage)	CIP, Programs (Grow Green)
Construction runoff	Regulation, programs (Environmental Inspection)
Poor riparian vegetation	CIP (restoration projects)
Unstable channels	CIP (restoration projects)
Altered hydrology	CIP, programs, regulations
Future Problem	Regulations

Toxins in Sediment = 100 – min(PAH, pesticide or metal EII)

Sediment data are collected from the mouth of each EII-monitored watersheds and analyzed for PAHs, pesticides and metals. Sediment EII scores are intended to be representative of the toxic load for the entire watershed. The worst (lowest) EII component (PAH, pesticide or metal) is used in the calculation.

Litter = 100 – (Litter EII)

Litter EII component scores collected for the aesthetics sub-index are subtracted from 100 to identify reaches with litter problems. EII litter scores are based on a visual assessment litter quantity and type at the representative monitoring site for each reach. Potential solutions include creek cleanups organized through groups like Keep Austin Beautiful and further source investigation through creek walks or aerial photography analysis.

Bacteria from animals = min(nutrient or %algae EII) – (bacteria EII)

The bacteria from animals problem was constructed to identify reaches with low concentrations of nutrients (ammonia, nitrate and orthophosphorus) and algae (as characterized by the percent algae coverage component of the aesthetics sub-index) but high fecal bacteria indicative of fecal contamination from animal sources and not leaking wastewater infrastructure. Areas with high fecal bacteria concentrations that are influenced by runoff from high-traffic dog parks would exemplify high priority problem reaches. The dual use of the worst (lowest) nutrient or algae EII component allows for reaches that may have low instream nutrient concentrations because of high algal biomass accrual and are thus nutrient enriched systems. Example solutions include education programs like the COA Scoop the Poop campaign to reduce fecal contamination within the reach.

Sewage = 100 – average[bacteria EII and min(nutrient or %algae EII)]

The sewage problem was designed to identify reaches with both high nutrients (ammonia, nitrate or orthophosphorus) and fecal bacteria typical of areas affected by leaking wastewater infrastructure. Again, the worst (lowest) nutrient or algae component EII score is used to more accurately represent the level of nutrient enrichment present. Problem areas could be recommended to the Austin Water Utility for further investigation and remediation of failing wastewater infrastructure.

Nutrients (non- sewage) = (bacteria EII) – min(nutrient or %algae EII)

Effectively the inverse of the bacteria from animals problem, the nutrients problem is constructed to identify reaches with low bacteria and high nutrients or algae cover indicative of reaches affected by nutrient enrichment from excessive or improper lawn fertilizer usage or other sources. Note that EII scores are 0-100 (bad to good) such that the subtraction of a good bacteria EII component score from a bad nutrient or algae EII component score would yield a large nutrients problem score. Programs like the COA Grow Green education campaign and CIP projects to capture and treat stormwater runoff are example solutions that could be targeted to problem reaches.

Construction Runoff = (bank stability EII) – average(TSS, sediment deposition EII)

The sediment from construction runoff problem score was designed to identify reaches with stable channels but high instream total suspended solids (TSS from the EII water quality sub-index) and high substrate embeddedness (from the sediment deposition component of the EII habitat quality sub-index). The worst of left or right bank stability are used in the calculation. Bank stability is included in the calculation to exclude highly depositional reaches where the source of stream sediments is likely bank sediments from erosion of unstable areas. Revised regulations and increased environmental inspections for code compliance are potential solutions which could be targeted to problem reaches.

Poor riparian vegetation = 100 – [(vegetative protection EII/100)*(riparian width EII)]

The inadequate riparian vegetation problem was designed to prioritize reaches with both low quality (i.e., low diversity) and low quantity (i.e., narrow) riparian zones. The calculation is done separately for the right and left banks and then the worst is used to represent the reach. Division of the bank vegetative protection score by 100 effectively converts it to a weighting factor to modify the riparian zone width component. Riparian zone assessments are completed as part of the habitat quality (a.k.a. physical integrity) EII sub-index. An optimal EII reach would have wide and diverse riparian zones on both sides of the creek. Stream bank restoration and re-vegetation are potential solutions for problem areas.

Unstable Channels = 100 – ¾*bank stability EII – ¼*channel alteration EII

The unstable channel problem score was designed to identify unstable creek reaches. The differential weighting of bank stability and channel alteration ranks altered, unstable reaches with the highest problem priority followed by unaltered, unstable reaches. The unstable channel problem will and the construction runoff problem are effectively mutually exclusive. Bank stability and channel alteration are collected during the habitat EII sub-index. The worst (lowest) of the left and right bank stability EII scores are used in the calculation.

Altered Hydrology (current) = 71.321 – 0.896 * F_{Ln} + 3.675 * ln(Q_{90})

The current altered hydrology problem was developed from a multiple linear regression of EII aquatic life scores versus a set of metrics describing the flow regime of the reach by the WQM team (Glick et al 2009). The selected flow metrics, calculated from mean daily flow records, are:

F_{Ln} = Average number of times mean daily flow is < 0.1 ft^3/s (Ritcher et al 1989)
Q_{90} = Daily flow rate exceeded 10 percent of the time, or the 90^{th} percentile

Flow metrics will be calculated from the output of SWAT models for all reaches for a pre-determined length of time preceding the evaluation year. The targeted problem is altered hydrology including both lack of baseflow and flashiness in response to runoff events. Flow is most likely the best predictor of future environmental conditions and can be predicted with SWAT models even in watersheds without continuous flow monitoring with reasonable accuracy. Because of the reliance of aquatic life community function on flow regime, hydrology is likely to be a good predictor of aquatic life integrity.

Future Problem = Future Altered Hydrology Problem – Current Altered Hydrology Problem

The future problem score is simply the difference between the future altered hydrology problem score, calculated using the SWAT models incorporating predicted future land use, and the current altered hydrology problem score. Highest priority reaches would be reaches with more stable flow regimes now that are threatened in the future to exhibit flow regimes that lack baseflow and are more flashy in response to runoff events. A potential solution to future problem reaches would be targeted regulatory action to limit connected impervious cover and provisions for specific types of stormwater controls.

Individual problem scores will be scaled so that the minimum problem score is equated to 0, the maximum problem score is equated to 100, and all intermediate scores linearly scaled accordingly. Scaling is done separately for each problem. Scaling aids in data interpretation, preserves the rank order of reach problems, and is consistent with both the EII format and the scoring procedures used by the flood and erosion missions. Although scaling creates a “moving target” and changes from year-to-year, the problem scores are not intended to be used to measure solution success. The positive or negative impacts of solutions are to be measured using either the raw (un-scaled) problem score or directly by EII scores. EII scores will continue to be the overall measure of environmental integrity for a given sampling reach or watershed. Problem scores will be used to direct solution implementation. Problem scores may be combined as necessary for use in the mission-integration process. For CIP program uses in relation to the mission integration process, the poor riparian vegetation, unstable channel, fertilizer runoff, and toxins in sediment scores will be summed and then scaled 0-100 to generate a water quality CIP problem score. This score will include altered hydrology in the future once SWAT model efforts have been completed.

Results

Altered hydrology and future scores are still in development, pending completion and calibration of SWAT models. Scores presented here do not yet include these problem scores. For each reach, problem scores with available data have been calculated and are shown in comparison to overall reach EII scores (table 2).

Table 2. Individual problem scores by EII reach (scaled 0-100) for most recent EII sampling (2005-2007).

Reach	EII	Toxins	Litter	Animals	Sewage	Fertilizer	ConstTSS	RipVeg	Stability
BAR1	53	36	21	56	71	44	76	84	1
BAR2	81	36	53	21	42	79	49	10	31
BAR3	86	36	21	22	43	78	57	11	9
BAR4	80	36	21	70	47	30	54	30	17
BEE1	84	24	5	37	45	63	43	38	21
BEE2	83	24	0	44	43	56	55	11	0
BEE3	76	24	0	33	55	67	57	10	8
BER1	77	26	21	52	57	48	39	72	37
BER2	78	26	0	48	53	52	58	11	0
BER3	83	26	5	56	40	44	56	30	15
BLU1	58	57	53	61	77	39	44	89	76
BLU2	59	57	79	60	88	40	44	72	41
BLU3	67	57	0	68	78	32	63	33	13
BMK1	61	56	42	86	75	14	6	93	76
BMK2	56	56	53	56	92	44	54	94	53
BMK3	49	56	74	63	100	38	0	91	100
BOG1	61	27	42	65	0	35	55	47	84
BOG2	63	27	79	34	69	66	45	90	71
BOG3	52	27	63	70	95	30	37	89	67
BUL1	79	28	42	63	51	38	54	87	17
BUL2	86	28	26	45	35	55	50	20	9
BUL3	90	28	0	49	21	51	47	20	9
CAR1	65	45	53	48	87	52	28	40	63
CAR2	67	45	21	57	69	43	43	72	47
CCE1	42	28	47	49	86	51	68	47	73
CCW1	43	52	21	65	0	35	22	29	55
CCW2	58	52	26	82	68	18	45	78	69
CTM1	54	72	63	61	81	39	57	81	39
DKR1	77	28	11	18	44	82	64	47	41
DKR3	46	28	63	45	84	55	87	20	8
DRE1	58	24	77	47	58	52	61	69	63
DRE2	64	24	53	29	57	71	87	30	31
DRN1	68	57	53	63	73	37	55	46	17
DRN2	58	57	58	74	71	26	40	83	48
EAN2	60	100	26	72	70	28	55	20	21
EBO1	55	79	79	64	87	36	53	87	56
EBO2	57	79	53	51	73	49	50	87	41
EBO3	45	79	79	48	87	52	78	94	28
ELM1	45	55	16	65	0	35	82	29	33

Reach	EII	Toxins	Litter	Animals	Sewage	Fertilizer	ConstTSS	RipVeg	Stability
ELM2	48	55	68	52	88	48	72	29	33
FOR1	35	54	100	65	0	35	81	56	64
FOR2	47	54	53	65	0	35	47	78	77
FOR3	64	54	53	59	57	41	33	93	81
FOR4	54	54	26	63	99	37	65	89	47
GIL1	65	21	53	47	90	52	47	56	57
GIL2	62	21	26	37	82	63	51	73	63
GIL3	60	21	53	45	94	55	66	61	56
GIL4	47	21	53	67	66	33	100	69	17
GIL5	59	21	58	39	92	61	44	83	77
GIL6	66	21	47	54	74	46	71	60	24
HRP1	46	69	63	63	88	37	82	90	29
HRS1	59	20	63	42	91	58	61	72	52
HRS2	57	20	74	56	94	44	73	67	44
JOH1	47	66	47	63	100	37	49	89	67
LBA1	80	28	5	46	38	54	26	69	47
LBA2	77	28	0	60	48	40	58	46	11
LBA3	72	28	16	67	53	33	69	50	1
LBE1	48	39	63	20	71	80	81	80	21
LBR1	70	34	0	53	62	47	72	20	9
LBR2	82	34	0	39	38	61	55	38	8
LKA1	81	22	5	22	49	78	36	40	48
LKA2	51	0	0	64	99	36	24	46	48
LKA3	77	21	11	39	47	61	42	80	29
LKA4	59	22	0	45	56	55	80	87	9
LKA5	69	20	5	74	64	26	45	84	41
LKA6	73	33	5	69	55	34	41	50	47
LKC1	70	27	53	42	82	58	62	40	37
LKC2	66	27	47	43	84	57	82	38	41
LKC3	62	27	68	29	79	71	66	94	27
LWA1	70	31	74	67	47	33	36	78	77
LWA2	70	31	74	38	61	62	34	93	55
LWA3	68	31	53	66	58	34	48	93	41
LWA4	59	31	53	93	78	7	76	87	21
MAR1	62	23	42	39	79	61	66	46	76
MAR2	55	23	68	5	55	95	32	99	28
NFD1	44	28	42	95	77	5	96	78	33
ONI1	71	32	0	40	71	60	42	0	49
ONI2	79	32	79	33	45	67	76	30	0
ONI3	76	32	0	39	58	61	36	89	51
ONI4	80	32	11	67	47	33	41	67	37
ONI5	82	32	0	79	55	19	50	11	16
ONI6	84	32	0	54	49	46	39	33	33
RAT1	50	36	21	21	66	79	72	91	44
RAT2	57	36	26	56	71	44	88	80	33
RIN1	72	40	32	53	56	49	65	38	28
RIN2	74	40	11	35	47	65	68	67	36
RIN3	51	40	26	54	62	46	45	83	71
SBG1	66	43	74	55	61	45	38	69	55
SBG2	65	43	26	59	71	41	29	73	51
SFD1	46	22	68	32	83	68	72	47	41
SFD2	52	22	53	14	61	86	49	97	89

Reach	EII	Toxins	Litter	Animals	Sewage	Fertilizer	ConstTSS	RipVeg	Stability
SHL1	44	59	53	59	96	41	71	96	40
SHL2	54	59	16	100	74	0	48	93	71
SHL3	61	59	53	76	58	24	47	69	37
SHL4	59	59	53	21	86	79	73	93	11
SLA1	74	26	53	33	51	67	54	33	37
SLA3	79	26	11	28	51	72	49	69	20
TAN1	59	53	79	0	51	100	51	77	83
TAN2	69	53	26	71	52	29	71	93	27
TAN3	59	53	74	76	73	24	15	77	71
TYN1	62	53	16	67	81	33	45	44	29
TYS1	60	68	26	39	82	61	28	87	48
WBL1	73	55	11	78	64	22	35	72	37
WBL2	77	55	5	53	40	49	46	20	11
WBO1	47	74	16	65	0	35	22	11	35
WBO2	59	74	53	48	81	52	42	93	56
WBO3	58	74	53	54	68	46	65	93	21
WLN1	71	31	53	64	61	36	46	53	60
WLN2	73	31	100	69	51	31	3	47	81
WLN3	75	31	47	65	57	35	60	64	17
WLN4	70	31	26	80	83	20	48	67	21
WLN5	72	31	11	85	60	15	28	53	51
WLR1	48	61	89	64	97	36	44	90	73
WLR2	55	61	53	63	88	37	47	100	33
WLR3	58	61	42	74	82	26	34	100	43
WMS1	72	37	5	40	79	60	61	69	9
WMS2	68	37	42	16	62	84	51	53	28
WMS3	60	37	26	64	32	36	56	94	41

Maps of the individual problem scores for the most recent EII data (2005-2007) are presented using a 5-level classification system (from very low to very high problem severity) (figure 2-9). Additionally, the combined water quality CIP problem score has been calculated and presented (figure 9). Scores and maps will be generated annually upon successful completion of EII sample collection and data processing.

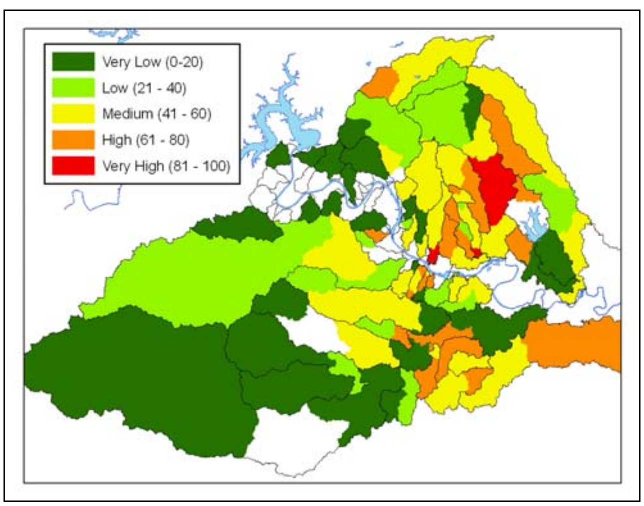

Figure 2. Litter problem severity.

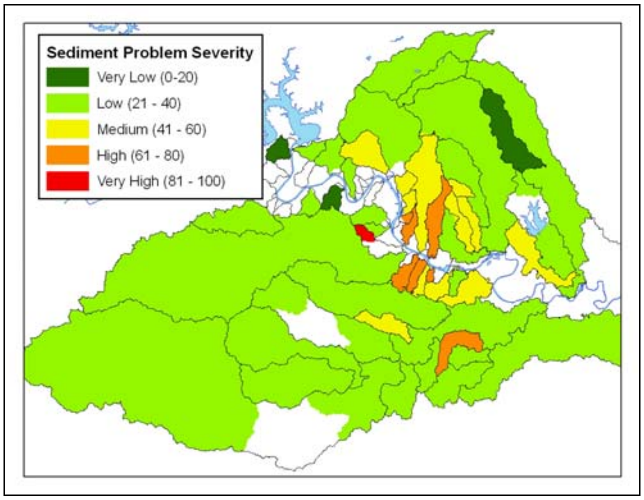

Figure 3. Sediment problem severity

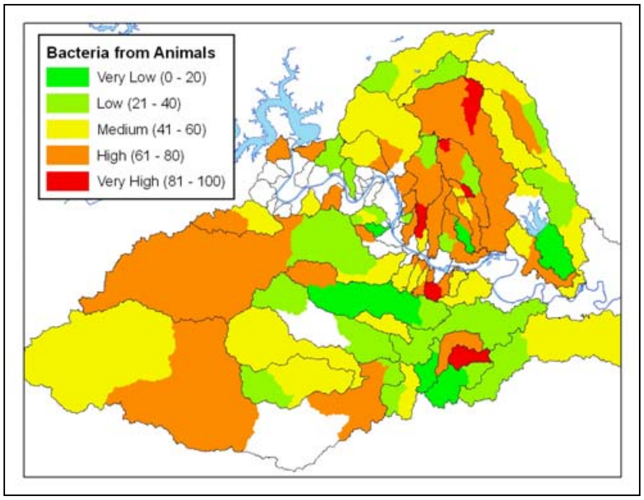

Figure 4. Bacteria from animals problem severity.

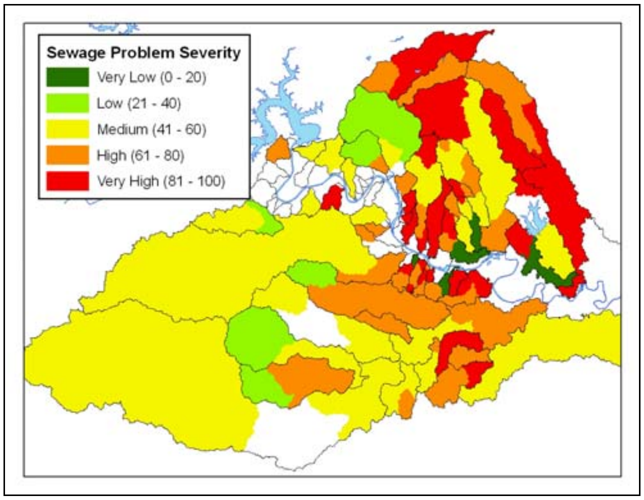

Figure 5. Sewage problem severity.

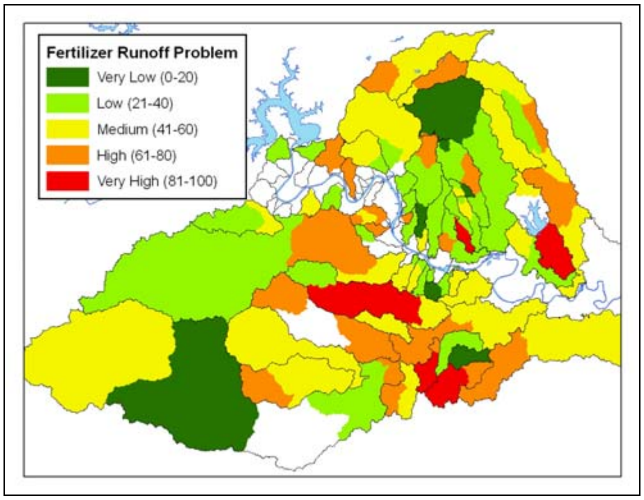

Figure 6. Fertilizer runoff problem severity.

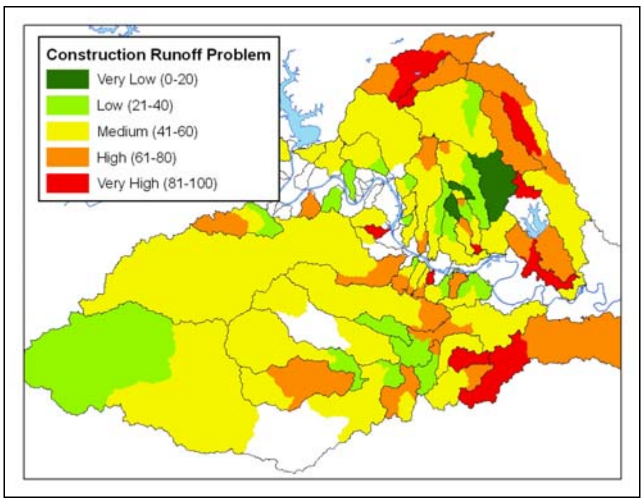

Figure 7. Construction site runoff problem severity.

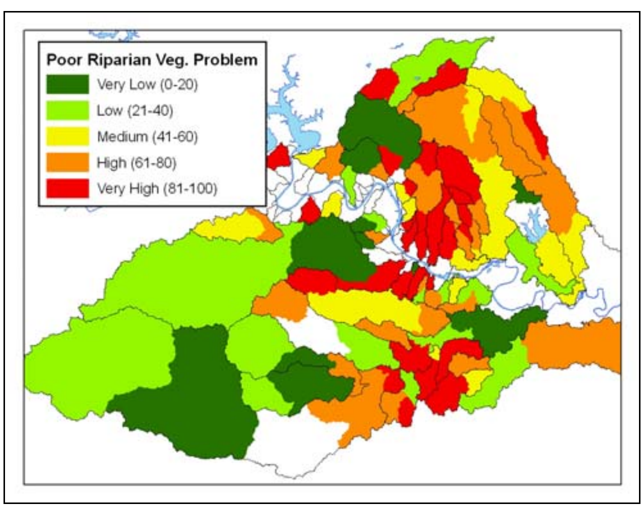

Figure 8. Poor riparian vegetation problem severity.

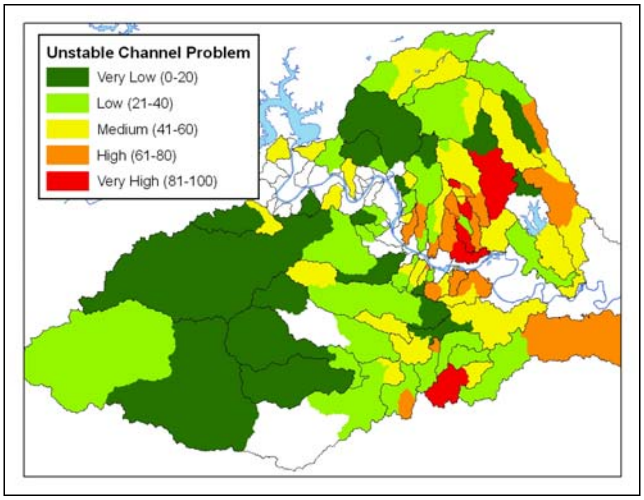

Figure 9. Unstable banks problem severity.

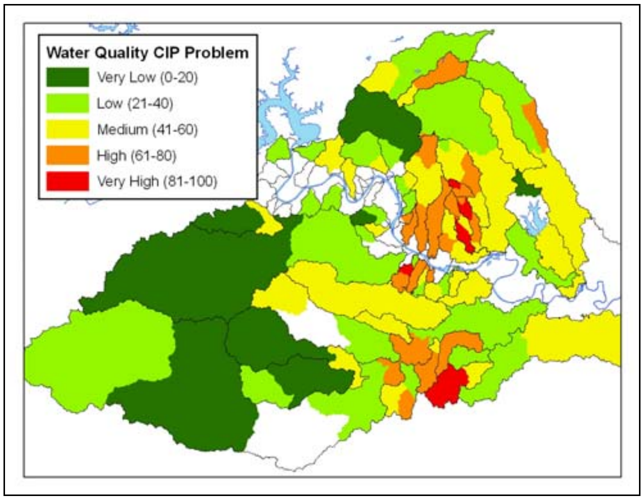

Figure 10. Water quality CIP problem score by EII reach for MIP process.

Conclusions

The revised problem score method provides prioritization of specific water quality problems with practical solutions. The calculation of the individual scores is simple and maximizes the specificity of the EII field observations to discriminate between pollution sources. The individual problems may be used to prioritize solutions for any of the programs or processes affected. Problem scores may be combined as necessary, as shown for the water quality CIP problem score for use in the mission-integration process. The EII will remain the overall indicator of environmental health.

References

City of Austin (COA). 1997. Environmental Integrity Index Water Quality Technical Assessment Methodology. City of Austin Drainage Utility Department, Environmental Resources Management Division. Water quality report series COA-ERM/WRE 1997-03.

City of Austin (COA). 2001. Watershed Protection Master Plan: Phase I Watersheds Report, Volume 1. Watershed Protection Report Series COA-WPD-2001-02. City of Austin Watershed Protection Department.

City of Austin (COA). 2003. Change in Environmental Integrity Index Values in the Austin, Texas, area (1996-2002). City of Austin Watershed Protection and Development Review Department. SR-03-06.

City of Austin (COA). 2005. Action Plan Items Related to EII Scores—Fiscal Year 2005. City of Austin Watershed Protection and Development Review Department. SR-05-08.

City of Austin (COA). 2007. Action Plan Items Related to EII Scores—Fiscal Year 2005. City of Austin Watershed Protection and Development Review Department. SR-07-03.

Glick, R., and L. Gosselink, B. Bai and C. Herrington. 2009. Impacts of Stream Hydrologic Characteristics on Ambient Water Quality and Aquatic Health in the Austin, Texas, area. City of Austin Watershed Protection and Development Review Department.

Richter, B.D., J.V. Baumgartner, J. Powell and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. *Conservation Biology* 10(4):1163-1174.