Environment Recovery Using Enhanced BMP
(Revision 1)

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The new approach to stormwater management developed in this paper, the Capitalistic Management Plan (CMP), has the objective of maximizing the environmental value of the rain received. This is done by establishing the dollar value of elements of the water budget and managing these elements to maximize value. A feature of CMP is that it maximizes evapotranspiration (cooling) and recharge and minimizes runoff.

A CMP implementation enhances a Best Management Practice (BMP) system by augmenting evapotranspiration and by managing a different set of rain events.

Local temperature is the main environment variable that can be impacted by development practices and stormwater management practices. Development site temperature is reduced by implementing two goals: “do not warm it” and “cool it”. The “cool it” goal is achieved through evapotranspiration. The “do not warm it” goal is achieved by requirements on the site albedo (use energy reflecting colors rather than absorbing colors). The extent of implementation on a site is established through cost benefit studies.

The local environment temperature is a function of the local sites. Sites developed under past and present BMPs discarded rain as runoff as soon as possible, before it had the opportunity to evaporate, cooling the environment. Sites developed under past and present BMPs are constructed without regard to solar warming. Blacktop and dark colors predominate, absorbing insolation, warming surfaces, increasing the thermal load on the evaporative cooling system that is being throttled down as its working fluid, water, is being discarded as runoff.

The present local environment temperature is a cumulative function of its present level of development. Local environment temperatures can be reduced by requiring new developments to implement less warming and more cooling, provided that enough rain is received.

Policy for CMP Implementation

The three step Policy for implementing CMP is straightforward: 1. Do not warm it. 2. Cool it. 3. Manage small rain events. This policy can be specified to developers through two constants and the set of events.

The after development albedo factor (KALB) defines the ratio of the after development albedo to the before development albedo. The after development evapotranspiration factor (KET) defines the ratio of the after development evapotranspiration to the before development evapotranspiration.

The proposed nominal values : KALB > 1.1 and KET > 1.1 produce less warming and increased local environment cooling, satisfying the first two steps of the Policy.

The set of events to be managed is: all rains less than or equal to the 2 year rain.

These constants should be specified by DEP as part of the permit approval. Townships could specify more conservative values in their "codes".

Observations:

Factors of 1.0 specify that warming and cooling after development will be the same as before development. Factors greater than 1.0 attempt to recover the cooler environment of pre-development days, less warming and more cooling. These factors can be useful in designing mitigation projects.

Townships SHALL be allowed to INCREASE the factors specified by DEP on specific permits. Townships SHALL NOT be allowed to DECREASE the factors specified by DEP.

Townships, watershed organizations, county organizations, etc. should recommend factors tailored for specific areas under their jurisdiction.

Surface Albedo and the Value of Reflectivity

Pennsylvania receives an average annual incident energy of about 150 watts per square meter. At $.05 per kwh the incident energy has the value of $265,878.47 per acre year. A 10% increase in albedo results in $26,600. less heating of an acre of the earth surface. Assuming a nominal albedo of 30%, the use of KALB = 1.1 would increase albedo 3%, saving $7,900. per acre year.

Water Budget and the Value of a Rain

A water budget is the tabulation equating rainfall to the sum of its components, principally evapotranspiration, recharge, and runoff. Table 1. presents water budgets of Valley Creek, Chester County, PA generated by Ron Sloto of USGS. The 20.8 mi^2 gaged watershed is rectangular shaped, about 2.7 mi. by 7.7 mi. The value of water budget items are developed as follows: Recharge seeps into the groundwater table and feeds creeks and wells. In Audubon, PA, well water costs $6.145 per thousand gallons, PLUS $167 per acre inch. At 5 cents per kwh, local PECO rates, the wet "T" shirt cooling of evapotranspiration is worth PLUS $3,500 per acre inch, 21 times as much. Runoff is being discarded, a lost opportunity, and is worth MINUS $167 or MINUS $3,500 per acre inch depending on how it would have been used. The rain value is the sum of the values of how it is used.

A CMP stormwater management system should maximize evapotranspiration, get as much recharge as possible, and minimize runoff, thereby producing more rain value per event.

The Valley Creek water budget of Table 1. shows the 5 year average annual value of the evapotranspiration for the watershed as $1.064 billion per year. Assuming zero impervious surface way back when the State was settled, the greater evapotranspiration would have been worth $1.168 billion. In the year 2001 with 20 percent of the land impervious the evapotranspiration is decreased and its current value is $.934 billion. (These values assume the same rainfall in the three cases, linearity, and equally effective means for evapotranspiration.) With the change in land use, going from 9% to 20 % impervious, each year the watershed is now getting $129. million less evaporative cooling than it got 15 years ago.

Table 1. Valley Creek Waterbudgets
Source: Sloto, USGS

					Area	20.8	mi^2	ET Value
Year	Precip	Streamflow	Runoff	Base Flow	Chg GWS	EvpoTr	Recharge	(millions)
1983	56.6	27	7.3	14.5	3.3	24.5	26.8	$1,139
1984	48.7	28.6	6.7	17.1	-4.1	22.2	21.8	$1,032
1985	42.7	15.6	4	8.6	0.4	24.8	15.9	$1,153
1986	47.7	20.5	5.3	11.9	0.1	24.8	19.5	$1,153
1987	40.6	20	3.3	13.2	-0.1	18.1	21.2	$841
Avg83-87	47.260	22.340	5.320	13.060	-0.080	22.880	21.040	$1,064

Small Events

The SCS Runoff Curve Number (CN) is a standard method of estimating runoff from storm rainfall. Curve numbers are related to the intensity of development of the site and to its hydrologic soil group. Hydrology texts and Technical Release 55 evaluate the defining equations and calculate the Direct Runoff from a site for appropriate amounts of rainfall and of CN. The data presented in Technical Release 55, covers rainfall of 1 inch through 15 inches.

A significant point in the table is that there is 0.000 inches of runoff from prime pasture (CN=39 TR 55, Table 2-2a) due to a 2 year 3.2 inch rain event. All of the rain would be utilized on site as evapotranspiration or recharge. Assuming equal amounts of ET and recharge this rain would be worth $5,867.20 per acre.

Development of a commercial and business site (CN=89) would result in 2.082 inches of runoff, leaving 1.118 inches for ET and recharge, worth $2,049.85 per acre. The lost opportunity value of the runoff of MINUS $3,817.38 is greater than the value of the water used.

The requirement on the stormwater management system is to utilize the 2.082 inches of projected runoff as effectively as the prime pasture. Note that the Direct Runoff table shows smaller amounts of runoff for smaller rains, assuring that the design will handle small events, and not tend to amplify a watershed runoff problem. The challenge is to implement the evapotranspiration of over half of the projected runoff.

The Chester County Water Resources Board Report 2 contains water budgets for French Creek, Valley Creek, Darby Creek, Crum Creek, W. Branch Brandywine Creek, more W. Branch Brandywine Creek, E. Branch Brandywine Creek, and Brandywine Creek @ Chadd's Ford. Data spans ran from 5 to 26 years. Ratios of evapotranspiration ranges from 0.620 on Darby in 1979 to 3.588 on the Brandywine in 1966. This wide range of values points out the difficulty in specifying a design to value for ET and R.

BMP Performance in Valley Creek

Results of my unpublished study of Valley Creek USGS Station #01473169 gage data , 7.4 years of data in the 8.4 year span, 11/4/86 through 3/30/94, are summarized in Table 2. I identified 152 events. Of these there were 127 events, 17 per year, that exceeded 150 cfs, (nominal flow is much less). Hydrographs of the events were scanned via algorithms to establish the rise times (20% to 80%) as an indication of the “scour hours”, the period of dynamic change in the flow. The average scour time was 1.67 hours. Discarding events that had peak flow greater than 1000 cfs left 118 events, 15.9 per year, that had an average scour time of 1.65 hours. (Note that the reduction was only 1 event per year. Were these 9 events 2, 5, and 10 year events?) It seems clear that Valley Creek is being battered by small rains. Small rain events are being amplified into habitat destroying disasters by the existing stormwater management system.

Solution: have the stormwater management system manage small events: all rains less than or equal to the 2 year rain.

Table 2. Scour Hours and Event Averages

November 4 1986 through March 30, 1994
7.4 years data in a 8.4 year span
Rise time, 20% to 80% = Dt28

	Event Count	Average Peak Flow	Avg. Dt28	Avg. Dt88	Avg. Dt82	Avg.Dt22	Sum Dt22	Range	Events per Year
Risefall	152	396.59	2.35	3.08	5.04	10.47	1591.23		20.54
Risefall2	127	424.87	1.67	2.83	4.88	9.37	1190.49	>150 cfs	17.16
Risefall3	118	361.4	1.65	2.79	4.93	9.37	1106.16	> 150 cfs	15.95
Risefall3	59	202.25	1.73	2.64	5.58	9.94	586.62	< 275 cfs	7.97
Risefall3	59	520.55	1.57	2.95	4.29	8.81	519.54	>275, 1.9'	7.97
Risefall3	64	208.87	1.73	2.59	5.46	9.78	625.79	< 300 cfs	8.65
Risefall3	54	542.17	1.56	3.03	4.31	8.9	480.36	>300, 2.0'	7.30
File:	Risefall.db		Risefall2.db		Risefall3.db				
TU_BK3;E			> 150 cfs		< 1000 cfs				
			h > 1.25'		h > 1.25'				

Workload

Workload is a measure of what needs to be accomplished to meet the demands of the job. The job of an acre of lawn was to evaporate and recharge the 1 acre inch of rain that fell. Following development of the acre, it could be half impervious, leaving a half acre the job of handling the acre inch of rain. The workload on the pervious half acre has been doubled. Table 3 presents data for a simple definition of workload and for the case where an area is dedicated to handle added amounts of water. In practice, a third section should be added to the table incorporating size of a “water storage area”.

The challenge in implementing CMP stormwater management systems is in supplying water to the working area at a rate that it can handle and over the time span needed. In the case of the half acre of lawn having to do twice the workload, it could work out that additional recharge could occur before the additional evapotranspiration could begin. The acre’s water budget would receive an additional half acre of recharge and lose a half acre of evapotranspiration, for a

Table 3. The WORKLOAD Concept

Evapotranspiration Recharge (ETR) System Design Requirements
For Climate Control and Recovery (CCR)

Site Impervious Ratio (%)	Area For ETR (%)	ETR Area WORKLOAD to Achieve Status Quo	+10% Recovery	+20% Recovery
0	100	1.000	1.100	1.200
5	95	1.053	1.158	1.263
10	90	1.111	1.222	1.333
20	80	1.250	1.375	1.500
30	70	1.429	1.571	1.714
40	60	1.667	1.833	2.000
50	50	2.000	2.200	2.400
60	40	2.500	2.750	3.000
70	30	3.333	3.667	4.000
75	25	4.000	4.400	4.800
80	20	5.000	5.500	6.000

Climate Control and Recovery

Site Imperv. Ratio (%)	Area For Living (%)	Area For ETR (%)	ETR Area WORKLOAD to Achieve Status Quo	+10% Recovery	+20% Recovery
10	85.00	5	3.000	5.000	7.000
10	80.00	10	2.000	3.000	4.000
10	75.00	15	1.667	2.333	3.000
10	70.00	20	1.500	2.000	2.500
20	75.00	**5**	5.000	7.000	9.000
20	70.00	10	3.000	4.000	5.000
20	65.00	15	2.333	3.000	3.667
20	60.00	20	2.000	2.500	3.000
40	55.00	5	9.000	11.000	13.000
40	50.00	10	5.000	6.000	7.000
40	45.00	15	3.667	4.333	5.000
40	40.00	20	3.000	3.500	4.000
80	15.00	5	17.000	19.000	21.000
80	10.00	10	9.000	10.000	11.000

Note:
1. Site impervious area includes the retention basin area.
2. Field fed for ETR is a “drip/spray irrigation area, slowly fed water from the basins for cooling and recharge.

Example: The Valley Creek watershed, at 20% impervious, could dedicate 5% of the 23.4 square mile watershed for CCR. The dedicated <u>1.2 square miles</u> should have a workload of 7 or 9 for recovery.

probable net loss of value since evaporation is 21 times as valuable as recharge. The solution is to feed water from retaining basins to the evapotranspiration-recharge area over the longer time span needed for the cooling process.

This complicates the location of management basins in housing developments and in industrial complexes.

Mitigation

Mitigation is the process of allowing a (non-compliant) site to be developed with the provison that another area will be used to compensate for the deficiencies of the principal site. Correcting for past development deficiencies is important to watershed environment recovery. This expanded application of mitigation is appropriate for urban sprawl as long as care and diligence taken with each case.

Watershed Environment Recovery Area, Examples

A Watershed Environment Recovery Area (WERA) is a site dedicated to cooling and recharge, to recover a portion of our environment, to mitigation.

The largest WERA in the state of Washington is the Grand Coolee WERA. The head of it is at the Grand Coolee Dam where hydroelectric generators provide power to pump water up and over the hill into Banks Lake from whence the water is used irrigate much of southeastern Washington. (The project was not designed as a WERA.)

The Valley Creek watershed is currently around 22% impervious, meaning that 22% of the land is not available for recharge or evapotranspiration. It implies that the 22% has lower albedo. Environmentally, this implies past practices are achieving more warming and less cooling, every day and every rain. Fortunately the watershed has a few miles of electric power transmission right of way and of abandoned RR right of way that could be made into a watershed environment recovery area (WERA). The cost benefits of implementing and maintaining a gathering, holding, dispersing stormwater management system can be calculated.

An additional source of water for the Valley Creek WERA is to apply the Grand Coolee concept to the Valley Creek watershed. Pump water from the Black Rock Dam impoundment, at Phoenixville, over the hill to Devault, and into the WERA. After many storms the Schuylkill River is high and muddy for a week. This excess water, headed for Cape May, should be welcomed by the Valley Creek watershed.

The Cannonsville Dam at Deposit, New York on the West Branch of the Delaware has the responsibility to provide late summer flow sufficient to keep the “salt line” downstream from Philadelphia. Management assures that water will be available by having the dam full plus for much of the spring. The overflow floods the West Branch, ruining fishing and wasting water. From April through June, the overflow could supply, via gravity feed, an 8 mile long WERA located beside Route 17. The recharged water would support streamflow for the next few weeks, allowing the post event dam flow to be reduced.

The Kinzua Dam above Warren in western PA is a candidate for a similar WERA.

Urban sprawl is a major problem. An environmental group, American Rivers (with friends) has posted a study "Paving Our Way to Water Shortages" on their web site, amrivers.org.master.com . The study examines the growth-sprawl of 20 US cities from 1983 through 1997. The amount of impervious acreage is impressive and disturbing. How can Pennsylvanians mitigate the impact of paving Pittsburgh and Philadelphia? Cooling these heat islands is a monumental task and opportunity. The major problem will be selecting sites for the WERA.

Corollary: The Golden Policy

The Golden Policy: send rain clouds unto your neighbor as you would have your neighbor send rain clouds to you, is a familiar phrasing. It is a very important environment management policy and basic to CMP. Rain clouds develop as the water vapor releases its latent heat to the atmosphere. When your up-weather neighbors implement conventional BMPs they flush their watershed of rain before sending water vapor to become clouds to shade you and give you rain. The end result of receiving weeks of dry air is drought. It is obviously difficult to send rain clouds to your neighbor if all you have received is dry air.

Because the Valley Creek watershed will not get the normal amount of rain clouds from the Letort watershed (which is being degraded) it could not send its normal portion of rain clouds to the Neshaminy watershed. The 22% impervious Valley Creek watershed sends significantly fewer rain clouds than it once did. A relative measure of the decreased neighborliness can be obtained from the decreased dollar value of evapotranspiration shown in the Valley Creek water budget, Table 1.

If major areas are analyzed, addressing Golden Policy objectives, the implementation would enhance watersheds ability to withstand the disruption of development.

The Future

With it apparent that policy impacts the environment, cognizant organizations can develop rational positions supporting development requirements for sites in their jurisdiction. The recently developed database of Pennsylvania's impervious surface might facilitate coordination between the groups and DEP to facilitate DEP's tailoring factors for specific areas. Additionally, these groups can advise Townships. Cooperation between groups is vital.

Opportunity is Knocking

The CMP approach of implementing stormwater management systems to achieve specific objectives will require practical answers to new questions. Evapotranspiration recharge area design may well be a variation on the present drip irrigation systems and spray irrigation systems used for land application of treated sewage. As yet, the firms implementing the several systems operating in Chester County have not priced the environment value, water budget, of their cooling and recharge. There was no market for them yesterday. The time to address these problems is now.

Tomorrow is here.

References:

Sloto, Ronald, 1994, Geology, Hydrology, and Ground-Water Quality of Chester County, Pennsylvania, Chester County Water Resources Authority, Water-Resource Report 2, Prepared in cooperation with the U.S. Geological Survey

Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, June 1986, National Technical Information Service, Springfield, VA 22161

Recommended Reading

Christopherson, Robert W., Geosystems: an introduction to physical geography, 4th ed., 2002, Prentice Hall, Upper Saddle River, NJ 07458, ISBN 0-13-061345-2