Emerging Paradigms in Storm Water Management: On site Passive Treatment Approach that Makes Sense Economically and Environmentally

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Two outdated yet ingrained philosophies of infrastructure design that greatly affect water use inefficiency are: **1. Domestic water supplies for indoor and <u>outdoor</u> use must be of drinking water quality**, and **2. Storm water is a waste product that must be shed off the property as quickly as possible**. Both philosophies evolved to extensive regulation, and construction standards for an expensive infrastructure procedure and system structure.

INTRODUCTION:

In the last century water management practices for water supplies and waste water disposal have changed very little in the form of philosophy or approach in design. In summary centralized filtration and treatment systems procured water from locally available sources be it surface or underground aquifers, polished it to drinking water standards, and through pressurized piping systems provided “running” water at the consumer end.

Pressurized domestic water supplies have a historical rationale based in sound Public Health Policies and indirectly have been adapted to support the technical shortcomings of conventional sprinkler delivery systems. In drier western states climates, however, 2/3 of the domestic water supply use is consumed for outdoor applications. The irrationality is that we clean and polish water sources to impeccable EPA drinking water standards and then post-contaminate 2/3 of this water with fertilizers so the plants can grow. The many contaminants we have removed are nothing more than nutrients needed by plants and already present in raw water.

At the other end used and “dirty” water was channeled into larger low pressure piping systems and channeled either as a direct discharge, or to treatment facilities to “clean” the water before it was discharged. For the most part the systems were hidden underground or located in remote areas of the community, and the average consumer knew little of the dynamics or structure. As long as water flowed when the faucet was turned on and the “toilet flushed”, life was good, and there was no need to fix something that is not broken.

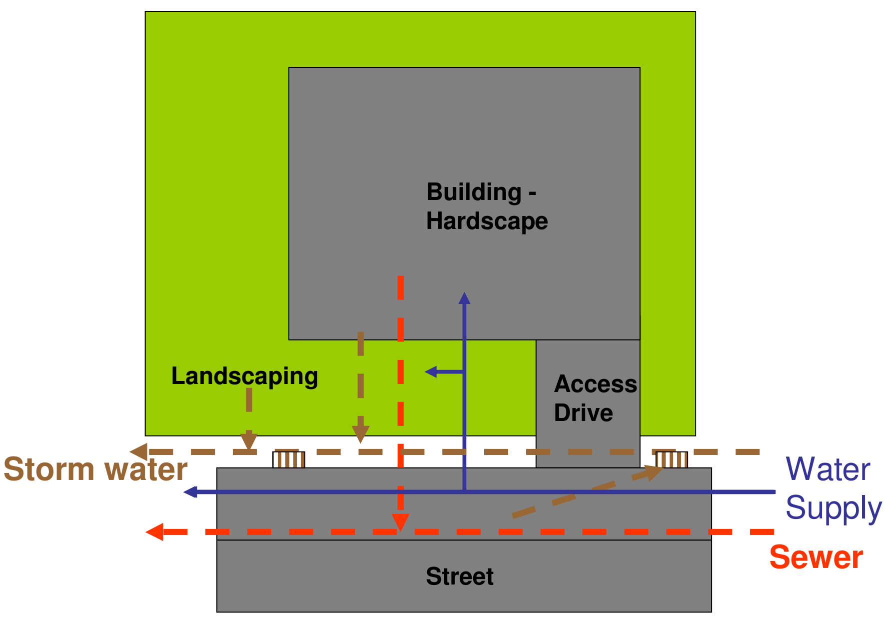
Population increases, migration shifts to live in “sunny” desert environments, drought, and higher volume and quality demands have provided supply pressures on existing water supplies. In many locations supply shortages are reaching a critical level. On the waste water side - pollution, environmental degradation, treatment costs, increased discharge regulations, and public awareness have increased pressures on improving the disposal of waste water.

Though intended for storm water relocation, conventional "curb and gutter" designs are also by nature street litter and pollution drains. Litter, animal droppings, automobile wash water, engine drippings, eroded soil etc. are simply intentionally or naturally washed away into the storm drain system to be dumped (or occasionally treated) somewhere downstream into larger bodies of water (rivers, bays, oceans).

CONVENTIONAL DESIGN

While physical buildings and surrounding areas have an infinite variation in form, size, occupancy and function; in terms of water management all community structural developments can be summarized in the following diagram of Fig.A

Fig. A – Conventional Infrastructure For Water Management



Any development whether it is a single family house, a high rise building, a shopping mall or sports complex must have access by a driveway from the street . The erected structure on the developed lot along with the traditionally impervious surfaces of streets, parking lots and access driveways form a water shedding surface. In most developments the cumulative total of hardscape (grey areas) often exceeds the pre-development hydrology of the vegetative areas (green areas).

Buildings are often surrounded by variable sizes and designs of landscape areas for functional and aesthetic purposes. Landscape areas may be small landscape gardens, small turf areas or large athletic fields on specific developments. Although absorptive landscape areas can traditionally absorb some of the water from rain events, the current practices of using traditional soils with a compacted clay content combined with code driven surface slopes of 1% or larger cause rain water simply to shed to low points of the property. Thereby to manage the overall cumulative storm events shed by all the hardscape and partially by landscape areas, the common wisdom was and is to construct a curb and gutter system at street level. These systems, though mathematically functional on the initial design plans are frequently overwhelmed by real life storm events due to plugged debris at catch basin openings, sediment accumulations in the transfer pipes, or downstream cumulative back-up. The net result is temporary flooding events.

Just as a storm event is composed of many individual rain-droplets, localized flooding is caused by the bulk accumulation of storm water run-off from many individual lots. While many perceive this as a necessary evil imposed by mother nature in an urban setting – the common events are not only a public safety hazard, an environmental pollutant, but sadly a total waste of a precious resource – free distilled water!

The **current challenge** in storm water management practices has been on **how to reduce and mitigate pollutants** that are discharged to the final recipient bodies of lakes, bays, streams, and ground water formations during storm events. Three general categories of pollutants are of concern and can be summarizes as follows:

1. The broad introduction of **nitrates** and **phosphates** that stimulate algal growth in the readily visible areas of surface water systems.

2. The visible **floating gross pollutants** of aesthetic concern in the form of visible floating debris, paper products, pet waste, agricultural litter and human refuse.

3. **Suspended** and **dissolved solids** of various chemical makeup including automobile crankcase drippings, fuel spills, soaps and detergents from vehicle washings, landscape fertilizers and pesticides, and accumulated fine dust particles from roads and roofs.

The centuries old historical philosophy and model for storm water management was the physical establishment of "slope" and the simultaneous construction of "curb and gutter" systems having the sole purpose of moving water quickly to its final dumping ground. **"We have traditionally created not a storm water management system but a storm water movement system."** Unfortunately water in motion increases its kinetic energy which then translates to a growing erosive force that not only moves particulate material from the initial surface but creates a downhill destructive power.

The first picture illustrates how the sloped surfaces of a house, driveway, road, landscape surface all terminate in the curb and gutter structure. The crystal clear water that fell as a light rain event has already turned a brown color as road pollutants and landscape erosion are now in suspension as storm water is now in motion.

Particulates and debris moving towards the catch basin initially enter the below ground pipe and then start to restrict the catch basin openings reducing the open area. Diversionary devices merely stage the pollutants for entry during subsequent higher flow events or through bi-pass move the water mass with increasing energy to a lower collection device. However eventual plugged piping or miscalculations as to volume leads to system collapse and failure.

The answer to storm water management is not the creation of bigger and more expensive storm water <u>movement systems</u>, but **changing our philosophy and methods** to true water management systems that actually prevent and treat storm water pollutants.

When pollution issues were not in the forefront, the “curb and gutter” systems were convenient conduits to clean the immediate environment. Driveways and walkways were routinely hosed down, street traffic accident spills and debris were flushed to the nearest catch basins, street washers sprayed the streets, and the rain itself washed things “away”. In the process of cleaning the immediate environment we transferred pollutants to the larger bodies of water and assumed that someone else is going to take care of it.

Increases in population densities increased impermeable surfaces, and while engineering reconstruction kept up with water movement strategies, water pollutant dumping overwhelmed natural cleaning cycles and pollution issues came to the forefront.

Current initial BMP’s (Best Management Practices) evolved towards devises that filter and capture gross visible pollutants (floating debris). They include catch basin inserts, traps, filters, vortex cyclone flow devises, in line diversion screens, manhole baffles, and capture screens and floating barriers at final discharge points. **While gross pollutants account for the largest volume of contaminants from storm events, this pollutant category has the least amount of biological impact on the final receiving bodies of water**. The devices in general are efficient debris removers in light storm water flows, but are overwhelmed in larger flows and have to rely on the built in bi-pass features. This group of BMP’s was an “add on” improvement to existing “curb and gutter” systems, but did not change the philosophy and structure of a “curb and gutter” system. A higher maintenance schedule to clean and service these devices has to be implemented. The eventual collection and disposal of these wastes improves aesthetics but does little to prevent the inflow of phosphates or nitrates.

Storm water detention and retention structures in the form of pits and basins became a BMP alternative to address the collection of sediment pollutants which were the primary source of soil phosphates. The theory was to slow the incoming water down into manmade ponds and allow some of the particulate matter to settle to the bottom of the pond and only allow slower and less contaminated surface flows to continue to the major receiving waters. Surface debris could be skimmed off while the soil sediments settle.

While this BMP has become, mostly by regulation, a current “state of the art” requirement for storm water mitigation, the model by nature creates a long list of other spin off problems, and it is questionable that this BMP actually adds to the environmental equation of improving the quality of the terminal receiving bodies of water.

1. Retention pits require the acquisition of considerable real estate acreage, in some localities at great expense. In Texas 20 acres of development require 1 acre of detention ponds, areas that now have no revenue base for tax collection or rentable space for developers.

2. The construction of detention pits in itself loosens considerable locked phosphate material in the soil, suspends the material into muddy water which during overflow storm events passes on the phosphate laden water to the final receiving waters.

3. Retention pits become a safety and liability issue and as such are frequently fenced as an added preventative expense. The fences in turn become wind blown filters for flying paper and debris.

4. The pits become mosquito breeding areas with associated disease vectors for horses and humans in residential areas.

5. In some areas the pits attract nuisance geese which in turn add to the deposition of soluble phosphates and nitrates.

6. The first incursion of silted muddy water seals the bottom infiltrative interface of the pit, and as such the pits do not recharge ground water as theorized.

7. The steep, soft inner embankments and water line areas are not conducive to support maintenance equipment that could clean or service the pits, and post construction budgets never account for routine maintenance of these structures. The steep side walls continue to erode during every rain event.

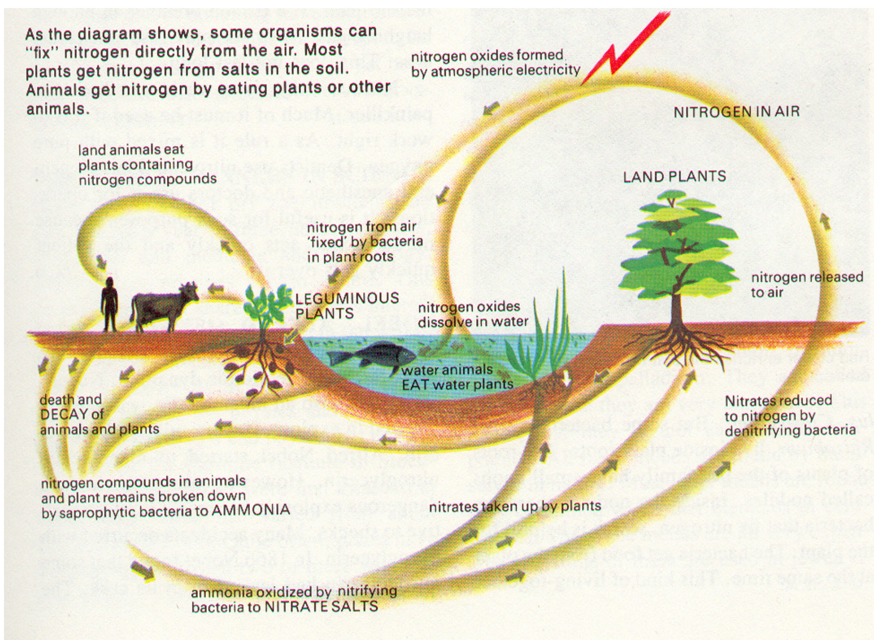
8. In wet climates the pits remain in a steady state of muddy water as phosphates and pollutants are in suspension with ongoing transfer of cloudy water to downstream water formations. In dry climates, storm events evaporate creating the conditions for the germination and proliferation of weeds. Desirable biological ecosystems rarely develop in pits due to extreme fluctuating water levels in a short time line. The “wetland” may have been created on paper but not in function.

9. Accumulation of leaves and other organic debris in the pits settles to the bottom and initiates an anaerobic environment which depletes oxygen and produces methane and hydrogen sulfide gas emissions.

10. The perceived client value is zero.

If the ecological goal in storm water management is the reduction of pollutants that initiate algae blooms and consequential oxygen deprivation in the final recipient bodies of water, then the focus in storm water management must be the reduction of **nitrates** and **phosphate** sources. Unfortunately BMP's that tend to augment conventional "curb and gutter" <u>water movement systems</u> cannot mitigate the reduction of these contaminants and in some cases actually contribute to the increase of these contaminants.

<u>Nitrates</u>: Nitrates (or NO_3^-) are the negative anions of a broad spectrum of basic chemical compounds commonly identified as sodium nitrate, ammonium nitrate, potassium nitrate, calcium nitrate, nitric acid etc. Most nitrate compounds are soluble in water and as such will travel anywhere that water goes. Holding a net negative charge, they can travel great distances in soil which by nature also carries a net negative charge. As such the dissolved compounds can relocate to ground water formations or larger bodies of water great distances away from its point of origin. Once formed there is no non-biological chemical reaction in soil that can precipitate or neutralize the compounds. Nitrate movement and biological absorption become part of the planet's nitrogen cycle.



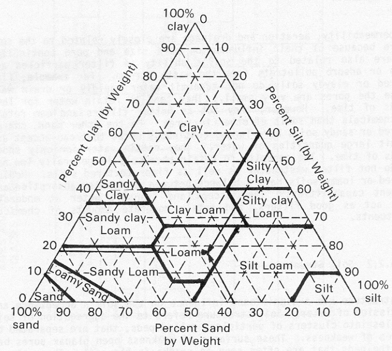
Nitrate production is ubiquitous and always present in storm water runoff not only from the wash out of excessive fertilizer applications, but also from the natural presence in thunderstorm rain events, and washings of surfaces exposed to automobile exhaust. Because nitrates are so highly soluble and negatively charged, an effort to control nitrate pollution by conventional "curb and gutter" systems can not happen because one must actually stop water movement itself to prevent nitrate transfer.

<u>Phosphates</u>: The primary source of this group of nutrients is a natural rock mineral called phosphorite. It consists largely of calcium phosphate and is used as a raw material for the subsequent manufacture of phosphate fertilizers, phosphoric acid, phosphorus and animal feeds. Some level of phosphate is universally present in all soils of agricultural quality. (Soils with the ability to grow plants whether they are weeds, turf or commercial crops).

The planet’s soils can be categorized as a percentage and combination of three particle size primary components – **sand, silt, and clay**.

FIGURE A-2

TEXTURAL TRIANGLE DEFINING TWELVE TEXTURAL CLASSES OF THE USDA
(ILLUSTRATED FOR A SAMPLE CONTAINING 37% SAND, 45% SILT, AND 18% CLAY)



All three particle components are derived from weathered rock and reflect the chemical characteristics of the many rock composition minerals including the phosphorus bearing molecules. Phosphorus molecules, unlike the negatively charged nitrate molecules have a net positive charge, and as such bind themselves quickly to the negatively charged soil particles. While nitrates readily move with water as compounds in solution, phosphates generally only move as “riders” on soil particles.

Sands (0.05-2.00 mm) by nature are larger particles and primarily composed of quartz crystals. As such there is less surface area or physical affinity for phosphates to attach as compared to the larger surface area and negative charges available on silt (0.002-0.05 mm) and clay (<0.002 mm) particles. Effective BMP’s for Phosphate pollution control must integrate three source areas as **phosphate control equates to the control of erosion and relocation of soil particles:**

1. Prevention of soil erosion
2. Sedimentation and removal of settle able solids formed as sands and silts.
3. Prevention of movement of suspended solids in the form of clay particulates, generally known as “muddy” or “turbid” water.

Some current BMP’s can effectively settle sands and silts but cannot handle “brown muddy” water where the majority of phosphates reside. Specialized high volume pump activated mechanical filters can make an attempt on “muddy water” in limited volumes, but high operating expense, frequent service and breakdown makes these systems not a viable solution to storm water pollution problems.

EMERGENCE OF THE EPIC SYSTEM

In 1999 breakthrough technology identified as the EPIC™ system turned the world of irrigation upside down. Using a sand based rootzone, capillary physics for vertical water distribution and gravity for horizontal and drainage distribution, the passive system achieved 100% efficiency in irrigation, better turf quality and affordable low maintenance construction. Direct comparative studies demonstrated 58% less water needs as compared to sprinklers, and overnight the 2/3 water allocation in outdoor use for desert climates could be reduced significantly, without a change in landscape area, plant species or cultural habits.

	Sprinklered lot	**EPIC™ lot**
Domestic indoor use	107,500 gal.	107,500 gal.
Outdoor irrigation needs	217,500 gal.	91,350 gal.
Total water allocation	325,000 gal. (1 acre foot)	198,850 gal. (0.6 acre foot)
Adding storm water capture	325,000 gal.(1 acre foot)	107,500 (**0.3 acre foot**)

The non-pressurized system changed the first cardinal rule that irrigation water has to be pressurized and of drinking water quality. Irrigation could now be achieved with a number of water sources without any public health concerns. Domestic water, shower water reuse, and reclaimed water from sewage treatment plants could all be blended and be reused even in residential settings without any public health issues. However easier and more importantly, **the EPIC™ system opened the doors for efficient capture and reuse of storm water directly**. The system acted as a pre-filter for runoff sources prior to storage and then flipped as an efficient irrigation system during dry periods.

The above EPIC™ backyard provides 100% efficient irrigation and total storm water capture by collecting roof and hardscape runoff into system for irrigation reuse..

This changed the second cardinal rule in development design – Storm water has to viewed as a waste product and be removed from the property as quickly as possible. In recent years storm water capture and sub ground storage was made possible by a number of products from many different companies. Inexpensive void spaces can be created by fiberglass tanks, arched polymer structures, bladder systems and concrete voids. Unobtrusively placed under driveways, road side edges, or landscaped areas, the structurally sound storage voids could now store water indefinitely for future use not only for irrigation but also for fire reservoirs or heat exchangers for geothermal heating and cooling systems.

Landscape design and irrigation can become part of storm water capture and management. Landscape architects and civil engineers can directly team up to provide hydrological responsibility in the design phase of any new or restructured project. Lots could be custom tailored with climatic events and cycles to be totally self-sufficient for water irrigation needs with free water that came out of the sky. This is even possible in the driest parts of the country with less than 7" annual rainfall. Roof, driveway, and street runoff can become integrated into collection systems where water was pre-filtered, stored and then reused when needed. In wet climates the EPIC systems integrated sand filtration retention and absorption of contaminants to eliminate erosion, and cool the water prior to a clean discharge into existing infrastructure systems and destinations.

Table 2. PHILOSOPHICAL CHANGES OF EPIC™ SYSTEMS

CONVENTIONAL "CURB & GUTTER" SYSTEMS	**PHILOSOPHICAL CHANGE IN EPIC™ WATER MANAGEMENT SYSTEMS**
Allows substantial surface flow prior to catch basins. A process which picks up pollutants, debris and initiates soil erosion.	Picks up water close to origin, filters it and moves it quickly below ground for a non erosive controlled flow.
Provides no intermediate storage as water volumes increase with downhill flow transferred by ever growing structural pipe.	**EPIC™** systems provide immediate pre-filtered subsurface storage at 2.5 gallons per square foot or larger.
Storm water is dumped to a downhill receiving body of water	Storm water is reused for irrigation, and only excess cleaned water is optionally discharged to a final body of water.
Expensive infrastructure serves single purpose of shedding water quickly	Inexpensive infrastructure serves multiple purpose of drainage, irrigation, pollutant management and treatment.

<u>**The distinguishing structural changes in EPIC™ designs are differentiated from conventional practices in the following ways:**</u>

PLANTING MEDIA.

Conventional landscaping practices deal with the available native soils, frequently "fluffed" and augmented with mulch, "top soil", fertilizers and imported sod.
EPIC™ growing media consists of washed, highly porous sands, and fine gravel for infiltration structures.

SLOPE.

Almost all conventional landscape areas have a surface slope in order to shed water. Slopes are designed to prevent standing water situations as native soils do not provide adequate infiltration rates to move the water below ground. The establishment of slope however also means that water will now move horizontally in paths of least resistance and initiate a scouring or surface erosion of the profile. Pollutants are now in suspension and move towards the nearest collection basin.

In **EPIC™** systems, due to the high porosity of sands, landscaping can be perfectly flat and still allow surface water to move down through the profile. As such erosion is never initiated because the sand particles are too large to go into suspension, there is no erosive surface flow, and storm water is automatically being pre-filtered by sand before it leaves the system. Nitrates, phosphates and other pollutants are retained within the system as nutrients and only clean excess water is transferred to receiving bodies of water.

DETENTION.
Conventional landscaping designs and "curb and gutter" systems are designed for quick water movement strategies. Speed does not allow for pollutant absorption and treatment, and worse as previously mentioned contributes in adding to the pollutant load through erosion. All agricultural soils contain within their matrix a number of nutrients that are available to the growing plants. Nutrient absorption by plants is a relatively slow process of assimilation as the plants grow. Soil and its nutrients must be retained in the growing profile for eventual absorption into the plant physiology and not lost with run-off water.

Table 3. NUTRIENT AVAILABILITY AND REMOVAL BY TURF*

NUTRIENT	SOIL CONTENT RANGE IN POUNDS/ACRE	TURF ABSORPTION IN POUNDS/ACRE FOR EVERY 2 TONS DRY PLANT MATTER
Nitrogen (N)	400-8,000	80
Potassium (K)	800-60,000	40
Phosphorus (P)	400-10,000	12
Calcium	14,000-1,000,000	16
Magnesium	1,200-12,000	8
Sulfur	60-20,000	6
Iron	14,000-1,100,000	1
Manganese	40-6,000	0.8
Copper	4-200	0.08
Zinc	20-600	0.6
Boron	4-200	0.08
Chlorine	40-1,800	4
Molybdenum	0.4-10	0.0008

* From Chemical Equilibria in Soils. W.L.Lindsay, 1979. Wiley & Sons.

What the above table illustrates is that **control of erosion is paramount** if we are to address nutrient pollution to terminal bodies of water. A significant amount of nutrients are available in fertile soils whether they are naturally present or artificially added. If soils get eroded by runoff so is the "tag along" nutrient.

In **EPIC™** designs the use of low fertility sands, large particle sizes, and flat non-erosive terrain also means that nutrients that are available in the growing media do not move offsite. Additionally as indicated in the second column of Table 3. **EPIC™**systems can absorb and treat (through plant growth) **80 pounds of Nitrogen and 40 pounds of Phosphorus** per acre if these nutrients are deposited in **EPIC**™ systems from outside sources **(Treatment Capacity).**

CASE STUDIES:

On a small scale a number of installations reduced run-off issues by a paradigm shift of storm water capture and reuse as irrigation water. The following installation changed a direct roof drain discharge to an urban street collection system to an aesthetic grass parking area that acted as a sand filter during storm events. The small roof area provided adequate seasonal irrigation water to sustain the grass.

The following car dealership installed an EPIC landscaping in front of the building.

Storm water sheet flow is directed for absorption into the EPIC profile and reused as irrigation water. While irrigation requirements were reduced by 60% the pollutant control benefit was - as the new cars are washed just above or over the profile, soap solutions and wash contaminants are absorbed into the profile, converted to plant nutrients and contaminated water never reaches the storm drain system.

This town house in Willermie, MN installed the EPIC profile near a wetland area as storm water capture system directly from the roof and hardscape areas. The system provided direct sand filtration, and landscape irrigation for grass and planting boxes. Independent monitoring by the Rice Creek water shed reported overall runoff volume reduction by **56%** and a phosphate removal efficiency of **85%.**

On a larger scale, the Cambria Elementary School on the central California coast captures and stores storm runoff during the rainy winter months off a 12 acre site to be reused as irrigation water for the rest of the year. A community with limited water resources! Sound familiar? The challenge was to provide 130,000 sq. ft. of an all season, durable, multi use grass play fields at a community school site where water volume, delivery pressures, and logistics were not feasible to deliver the water resources for conventional irrigation systems. The unique solution provides a water conservation system that utilizes the harvest and storage of rainwater runoff, and efficient non-pressurized subsurface irrigation.

Cambria, California a small coastal community in 2002 was at a crossroads to expand a planned expansion of an Elementary school and grounds. Prohibitive and unavailable land costs in the community proper were not available, and the only available land was in the outskirts of the town where steep coastal foothills presented site development and erosion challenges and the added elevation rise prevented the delivery of adequate volume and pressure of irrigation water to the site. The Coast Unified School District under a bond measure and assistance by the California State Allocation Board for Proposition 47 contracted services with RRM Design Group (Architect/Civil Engineer), Earth Systems Pacific (Soil Engineer) to provide plans to solve the development objectives and satisfy the stringent water quality and erosion mitigation demands of the California Coastal Commission.

The main player in this conservation game was the EPIC™ system. The system is a versatile player as it acts as a collector, water distributor, filtration system and irrigation system all in one.

As irrigation requirements in this system are reduced by better than 50% over conventional practices, so is the required volume of storage. In the Cambria School, all of the stormwater runoff from the 12 acre campus's hardscape is collected and stored in a subsurface detention basin (2.0 million gallons) in linear pipe underneath the main 87,000 sq. ft. playfield. Sufficient water is collected during seasonal rains (Average 17" per year) to supply all of the campus's irrigation needs for the rest of the year.

Cambria Elementary School, Storm water collection and Storage system under primary play field. (RRM design)

The best part of this design solution is the functional simplicity, low-tech/low maintenance components, reduced water usage, storm water management and saving the community's potable water supply for drinking – not landscaping. This is a sustainable project that harvests free rain water (during the rainy winter months) and stores it in an underground chamber system till when it is needed for irrigation. The storage system does not use up additional land space, is not subject to evaporation, nor does it promote algae growth to compromise water quality. Pre-filtration through the EPIC™ profile prior to storage minimizes sediment accumulations in the reservoir in the long term.

This Innovative Low Impact Development design shows how large institutional facilities can be self-sustainable by changing the way they look at storm water. Capturing every last drop provides sufficient irrigation water for their landscaping needs for the entire campus. Not just for a week or month but for year, after year, after year. This avoids all runoff issues and truly promotes a Green Bottom line.

Completed Cambria Elementary Fields. Note flat laser level design of fields on tiered campus levels. (Sipaila)

Cambria School runoff filtration and water harvesting strip at mid section.(Sipaila)

Cambria School Primary Soccer field over sub-ground reservoir storage. Fall, 2006 (Sipaila)

Imagine, now that water sustainability is a reality on such a large scale for school campuses, this design concept being replicated across the country. Imagine the impact that this new EPIC™ system technology will have on the water resources of this country. Imagine if every new school ball field is actually self-sustainable. Imagine if every new residential or commercial development implements this to become self-sustainable in terms of water usage for all landscaping.

The ability to effectively control storm water movement through biological sand profiles provides opportunities to pre-filter, collect, store and reuse valuable and free rain water for secondary uses and benefits. Modifying this versatile EPIC™ BMP to many applications changes both the philosophical approach and desired outcome in many designs.

The paradigm shift in infrastructure design does not necessarily have to change the accustomed look and layout of familiar conventional design. A second look at the previously presented conventional infrastructure concept structure shows that we have no change in designated areas but what has changed in the EPIC Infrastructure is that:

- Storm water runoff passes through a sand profile for filtration to prevent erosion and pollutant transfer

- Storm water is linearly stored below ground to be reused as needed to provide irrigation, thus, depending on design, run-off is drastically reduced or eliminated totally.
- Domestic water supplies are not used for irrigation needs.
- Selected waste water sources can be integrated as irrigation water to reduce waste water treatment downstream.
- A natural reduction on all three existing infrastructure demands of water supply, storm water volume, and waste water treatment.

Fig. B – EPIC Infrastructure For Water Management