Plavel Water

Repurposing Single Use Plastics for Drainage and Water Treatment Applications

Norman Hantzsche, PE[1] and Matt Woll[2]

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Introduction and Overview

This document describes an innovative method for repurposing large quantities of used plastic water bottles and other single use plastics for use in common drainage and water treatment applications, along with a plan to begin implementing these methods in the U.S. and beyond. We see the efforts in the U.S. as the "proving ground" for the gradual expansion of these PET repurposing practices around the world, where there is a desperate need for plastic waste solutions.

Plastic waste is everywhere - on the ocean floor, remote islands, buried underground in landfill sites and in the food chain. Humans are now estimated to be buying (and discarding) plastic beverage containers at the rate of one million bottles per minute. In the U.S. water bottles are consumed at an estimated rate of three million bottles per hour. Although highly recyclable, the percentage of water bottles recycled is actually very low - about 30% in the U.S. and less than 10% worldwide. Recycling rates for other single use plastics is even less or non-existent. Most plastics end up in landfills or the oceans, where the accumulation of plastics has come to be recognized as one of the worst environmental scourges of our time.

Water engineers with Questa Engineering, a California-based environmental engineering firm, have pioneered practical ways in which used PET plastic water bottles and other packaging, when properly prepared, can be used as a substitute for gravel and other commercially manufactured plastic products used in various types of drainage, water storage and water filtration applications. The potential uses include: (a) foundation drains and French drains; (b) sanitary drainfields (i.e., leachfields, soak trenches); (c) stormwater detention and bio-retention systems; (d) rainwater harvesting; and (e) a variety of water and wastewater filtration uses such as trickling filters, septic tank effluent filters, greywater treatment, constructed wetlands, and water filtration for aquaculture, koi ponds and other landscape water features. The term "*plavel*" (**pla**stic + gra**vel**) has been coined to refer to plastic waste repurposed in this manner.

Plavel offers a major and heretofore untapped opportunity to recover and convert single use plastics into a viable and useful building material, which can be used in and near the communities where the plastic waste products are generated, in ways that provide significant benefits to water conservation, environmental quality, public health, sanitation, and green building design. To turn this opportunity into reality, a plan has been devised based around the formation of a non-profit organization, *Plavel Water*, as the core entity to develop, produce, fundraise, promote and mobilize communities in the

[1] Principal/Managing Engineer, Questa Engineering Corp., Richmond, California; nhantzsche@questaec.com
[2] Engineering Associate, Questa Engineering Corp., Richmond, California; mwoll@questaec.com

repurposing of single use plastics as *plavel*. The approach recognizes and seeks to combine the need for broad community buy-in and participation, relatively simple production methods, and the growing human disgust with plastic waste, along with a strong desire to be part of the solution.

Repurposing PET Plastic

Background. Manufactured plastic products have been developed and used in the water and wastewater industry dating back to the 1970s. Primary uses have been as a substitute for stone and gravel, the traditional materials used in many water and wastewater filtration processes and in sub-surface drainage systems such as French drains, foundation drains and sanitary drainfields (**Figure 1**). The main types of plastics used in these products are recycled polyethylene, polypropylene, PVC and polystyrene.

The idea of repurposing PET plastic bottles for use in water and wastewater treatment systems has been around for the past 10 to 15 years, but not widely publicized and generally only in connection with academic work and one-off projects. Promising results from a 2005 study of PET plastic bottles used in a greywater-wetland treatment system in Costa Rica[3] caught the attention of engineers at Questa. It led to pilot testing the practicality and effectiveness of using plastic bottles for sewage treatment systems, done in cooperation with researchers at the University of California at Davis. This was followed by design and implementation of a tertiary wastewater recycling system for the Human Needs Project[4] – a community water and sanitation center serving the Kibera Slum in Nairobi, Kenya. The project utilized 150,000 waste plastic bottles for biofilm[5] elements in various parts of the treatment process, including upflow, horizontal and trickling filters. Engineers at Questa have since expanded on the experience gained from the Kibera project, developing practical methods and designs for repurposing plastic bottles and other waste plastics in a wide variety of drainage, water and wastewater applications, which are ready for implementation on a large scale.

Keys to PET Repurposing:

- As a raw building material, PET plastic has similar features that make stone and gravel desirable for water and drainage uses, such as durability, strength, high specific surface area and resistance to decay.[6]
- Transforming PET plastic into gravel- or cobble-sized pieces or chunks allows it to be packed or aggregated like gravel.
- Irregularly shaped pieces of deformed PET plastic, when packed together, produce an unusually strong structural matrix, with high permeability, porosity and specific surface area[7], comparable or superior to those of stone, gravel and many manufactured plastic products currently in use.

[3] Dallas, Stewart. June 2005. Reed beds for the Treatment of Greywater as an Application of Ecological Sanitation in rural Costa Rica, Central America. PhD Thesis, Murcoch University, Western Australia.
[4] http://www.humanneedsproject.org/
[5] In a wastewater treatment system, biofilm refers to microorganisms that grow on rocks, sand or plastic to create a film. They grow on these surfaces by feeding off the organic matter and nutrients in the water that flows over them.
[6] PET plastic is estimated to take more than 450 years to decay in the natural environment.
[7] Porosity is the fraction of void volume over the total volume of a mass; specific surface area is the total surface area of solids per unit mass or volume of material

- Although PET is the preferred material and should comprise the bulk of the assembled plavel product, certain other hard waste plastics (e.g., caps, lids, other HDPE, PVC and PP) may be incorporated in minor percentages (e.g., 10 to 15%).

- Plastic bottles and packaging can be converted to *plavel* using hand-labor methods or relatively simple machines, making it widely and readily available to the developing regions of the world, where it could have an especially beneficial effect in addressing the need for water and sanitation improvements as well as the plastic waste menace.

***Plavel* Production Method.** *Plavel* can be formed from common PET bottles (0.5 to 2.0 liters) by: (1) twisting or otherwise deforming the bottle into a rope-like shape; and then (2) cutting the deformed bottle into gravel or small cobble-sized pieces or chunks (ideally 1 to 4 inches across), using a knife, paper cutter, cane knife or similar cutting tool. A pedal-powered cutting device we have developed can speed the cutting process. Plavel can also be formed by crushing into conical shapes, which is also the preferred method for larger, heavy-wall, and irregularly shaped containers and packaging such as plastic tubs, clamshells, and cartons.

The *plavel* pieces are then tightly packed into a durable (polypropylene or polyethylene) plastic mesh bag or netting for use in various drainage, water storage or treatment applications (**Figures 2** and **3**). The method is labor intensive, but relatively simple and especially well suited to areas where a large labor force is available or can be mobilized through community engagement. Mechanical systems to further speed the *plavel*-making process are under development.

PET Leaching Concerns. PET plastic has been studied for potential leaching ("migration") of harmful compounds due to the obvious concerns about possible health threats to people consuming bottled water, other beverages and foods packaged in PET plastic containers. Studies have found that potential leaching from PET plastic bottles into the water increases at very high temperatures, longer contact/storage time, and exposure to sunlight. The trace metal antimony, used as a catalyst in the formation of PET, has been found in bottled water at very low concentrations (safely within drinking water standards) under normal usage and storage conditions[8]. In a 2009 study[9], PET water bottles were indicated to be a source of contamination with xenoestrogens (endocrine disruptors), although the responsible factor was not determined. Other studies have concluded PET plastic to be generally safe for food and beverage packaging. PET plastic does not contain BPA or plasticizers, which are used in some plastics and of particular concern in regard to potential health effects.

There are critical differences between effects on bottled drinking water as compared with water that would be passing through or temporarily detained in the drainage, storage or treatment systems using *plavel*. These differences, which all contribute to significantly reduced potential for leaching in *plavel* applications, include: (a) generally cool temperature conditions below ground and in treatment

[8] Westerhoff, et al. "Antimony leaching from polyethylene terephthalate (PET) plastic used for bottled drinking water." 2008. https://www.ncbi.nlm.nih.gov/pubmed/17707454

[9] Wagner,M and Oehlmann, J. "Endocrine disruptors in bottled mineral water: total estrogenic burden and migration from plastic bottles." https://www.ncbi.nlm.nih.gov/pubmed/19274472

vessels; (b) no exposure to sunlight; (c) limited time for contact between water and plastic surfaces (e.g., mostly hours to a few days; a few months for rainwater storage); (d) dispersion and attenuation of pollutants in the soil in most cases; and (e) no anticipated connection to drinking water supplies. Plans are being made for water quality testing studies to provide information on flow-through leaching aspects of various plavel uses.

Opportunities for Repurposing PET Plastic

Potential applications of *plavel* for drainage, water storage and water/wastewater treatment are illustrated in **Figures 4, 5** and **6.** A summary is given **Table 1**, including the approximate quantity of repurposed PET plastic, in terms of number of 0.5 liter water bottles, for each example application.

Table 1.
PET Repurposing Applications and Water Bottle Use Estimates

Application	Assumptions	# of Water Bottles (0.5 liter)
Building Foundation Drain	1,500 ft^2 house; 150 lf of 9" dia. drain unit	5,000
French Drain	Residential yard; 100 lf of 9"dia. drain unit	3,000
Stormwater Bio-retention	0.6-ac commercial site, 7,500 gal stormwater retention/storage	90,000
Rainwater Storage	1,000 gal below ground storage, 12"dia. *plave*l drainage units w/liner	12,000
Greywater Treatment	Residence, upflow mixed media filter, 55-gal drum, 12" *plavel* layer	250
Sub-irrigation, Residential	100 gal/wk greywater, 6 raised beds, 3'x7', 12" *plavel* reservoir	11,000
Sub-irrigation, Community	Community garden, 50 raised beds, 3'x7', 12" *plavel* reservoir	94,000
Sanitary Drainfield, Residence	150 lf, standard gravity, ave soils, 1.3 ft^3 *plavel* per lf	15,000
Constructed Wetland*	Fijian village community greywater system	2,000
Recycled Water System*	HNP Kibera, 10,000 gpd, upflow, horizontal & trickling filters	150,000

* Actual quantities for constructed projects

Plavel Water - Nonprofit

A plan has been developed around the formation of a nonprofit organization, *Plavel Water*, as the core entity, to develop, produce, fundraise, promote and mobilize communities in the repurposing of PET plastic as *plavel*.

Local youth groups, other community organizations and volunteers will be trained and engaged in plastic collection, preparation and assembly of *plavel* products as a means of fundraising for their respective organizations, while also benefiting from an array of water and environmental educational experiences. Employees will be added to supplement volunteer groups in response to demand; and technical assistance will be retained as needed.

Plavel Water will: (a) develop product standards; (b) pursue approvals and acceptance for the various applications; (c) educate governmental, environmental, design and trade organizations and professionals; and (d) market and supply *plavel* products to the building industry. The initial focus of the effort will be the San Francisco Bay Area, with the aim of providing the impetus, technical support and a model program that can be adopted and readily put into practice by community-based organizations in other regions of California, throughout the U.S., and abroad.

Figure 1. Manufactured Plastics for Drainage, Water and Wastewater

Costa Rica Greywater Treatment Study, 2005

UC Davis Recycled Water Pilot Study, 2012

HNP Kibera Town Center, Nairobi, Kenya, 2013

Basic Plavel Preparation Method

Packing in Produce Bag

Figure 3. Plavel Preparation

Drainage Unit

Storage/Drainage Unit

Filter/Storage Units

Figure 4. Plavel Drainage, Storage and Filter Units

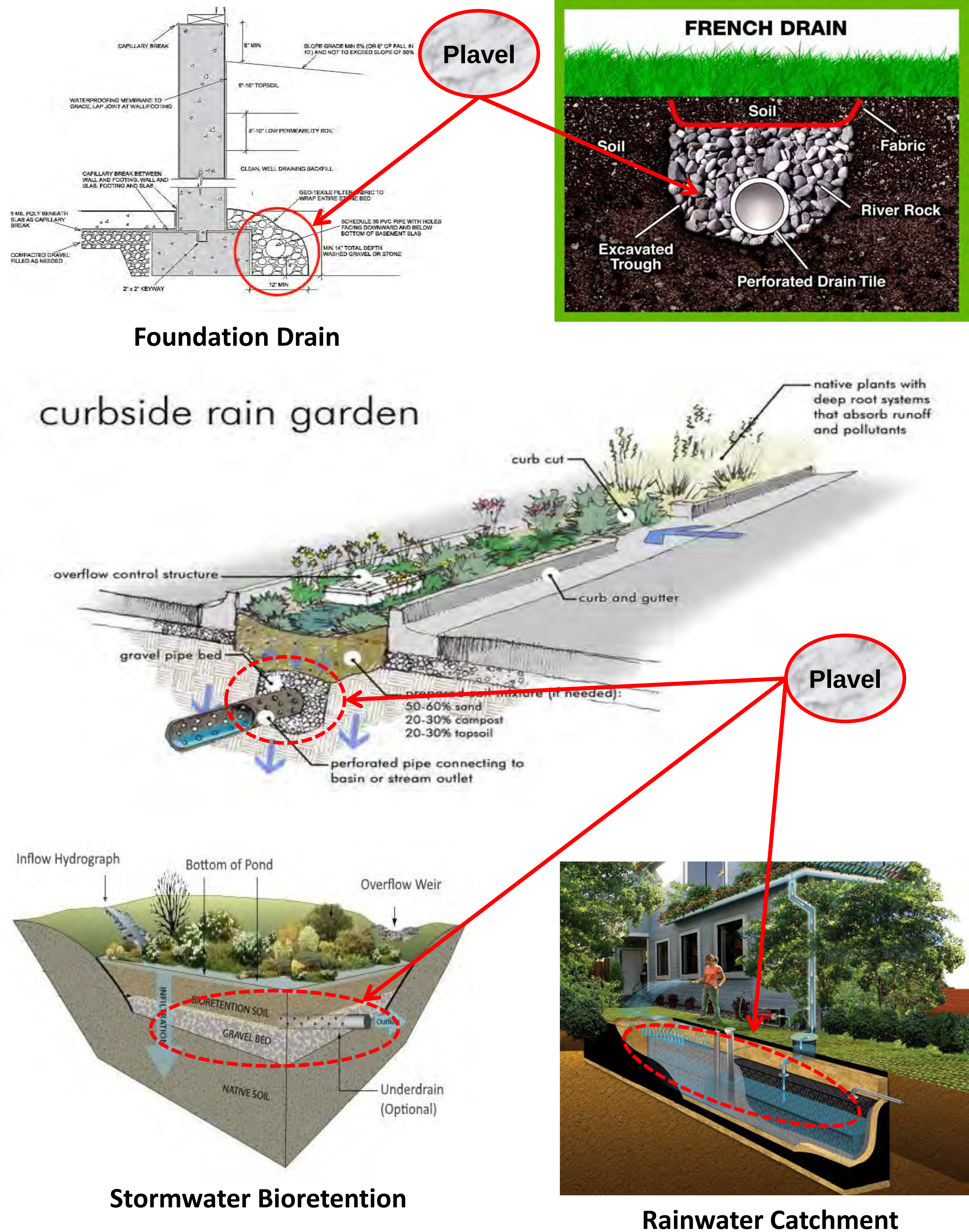


Figure 5. Plavel Applications

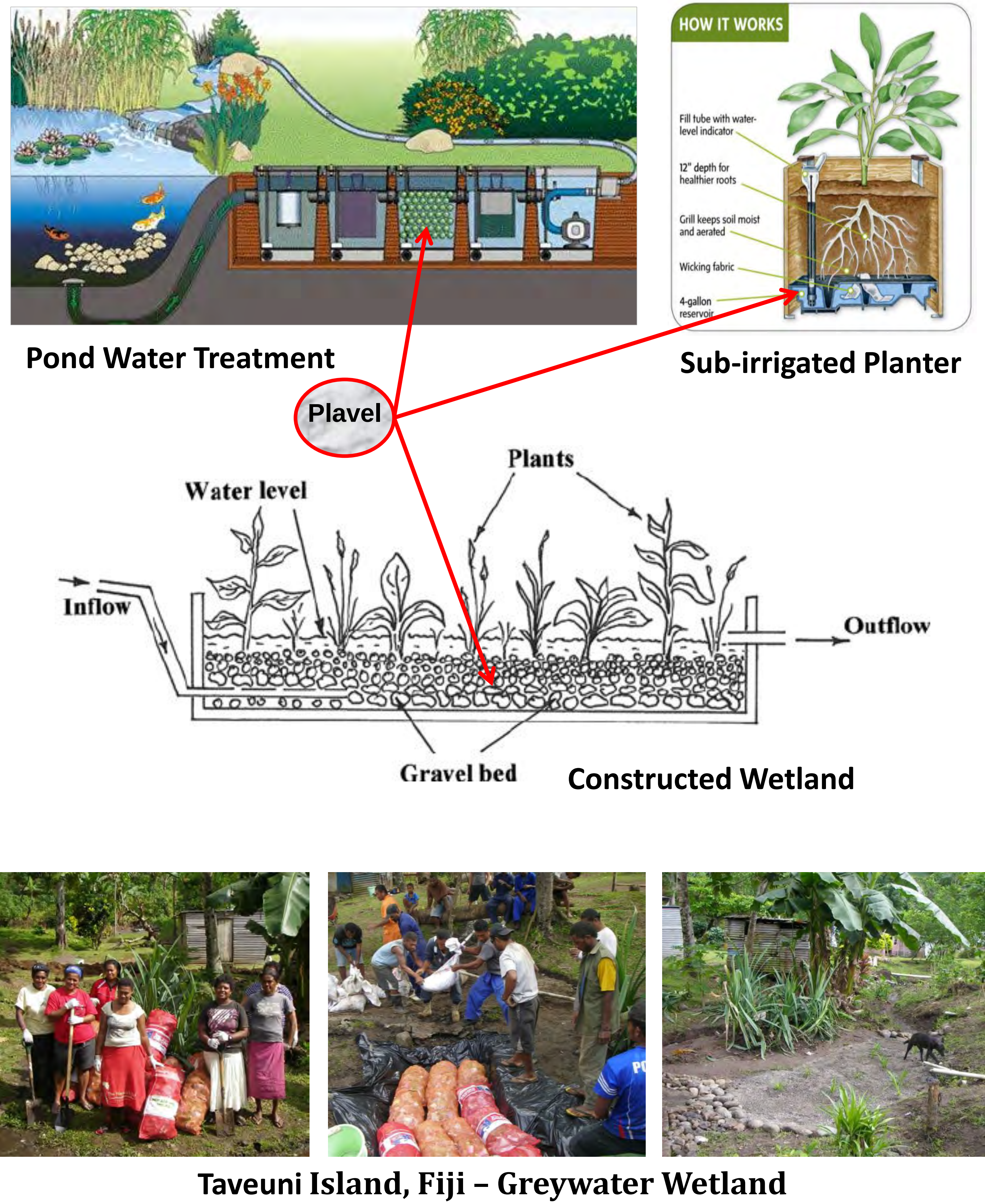


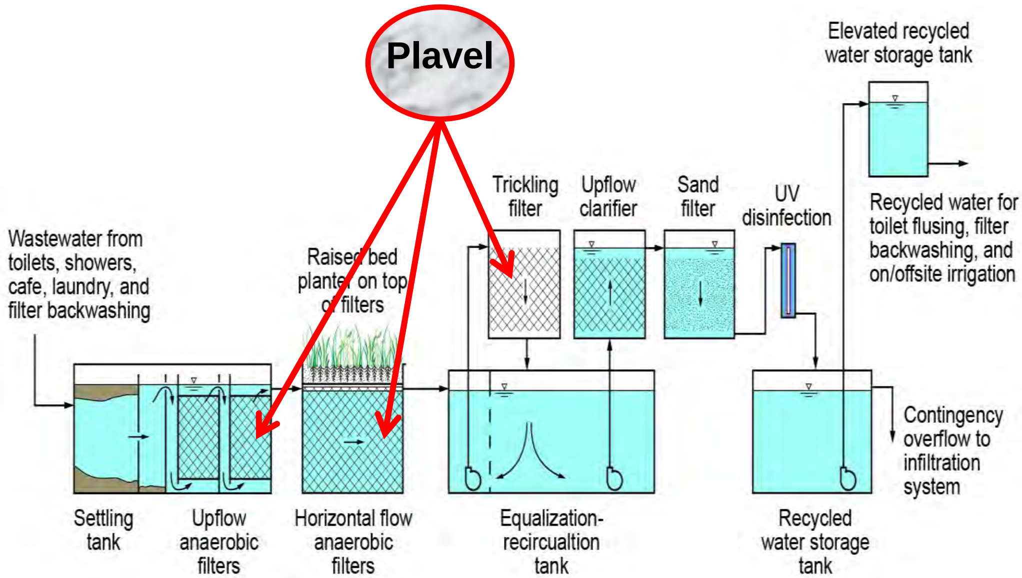
Figure 6. Plavel Applications

Human Needs Project

Kibera Town Center, Nairobi, Kenya

Tertiary Water Recycling System – 10,000 gpd

Plavel Used: 150,000 bottles



Wastewater Recycling Schematic

2004 Point Reyes Affordable Housing Project, California

27 apartments, 7 single family residences

Conventional Septic Tank – Drainfield Systems

Total Gravel Used: 600 cubic yards

Plavel Equivalent: 1.3 million 0.5-liter bottles

Figure 7. Plavel Applications