

## **Management of Dry Weather Flows in Semi Arid Climates Using Low Impact Development Technology**

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### **Abstract**

Urbanized semi-arid regions experience a significant amount of dry-weather flows in the form of return from excessive irrigation on suburban lawns. These dry-weather flows also carry significant amounts of nutrients from household fertilizers, which are discharged to receiving water bodies. These nutrients cause unsightly algal growth sometimes known as “urban slobber,” that result in oxygen depletion due to organic matter decay. These flow rates can constitute a large component of dry-weather flow in urban streams. The conditions of semi-arid climates are conducive to turn these flows into a more visible nuisance than in humid regions.

This paper explores the application of LID technology to manage dry-weather flows in semi-arid climates. LID’s infiltration-based controls can be deployed to intercept and treat nutrient-laden excess irrigation flow. The concept is illustrated in a subdivision in Los Angeles, California area by applying the LIFE™ model developed by CH2M HILL for simulation of LID hydrology.

### **Background**

LID has gained status as a mainstream stormwater management technology since its inception in the 1990s as an alternative to traditional best management practices for stormwater. The LID philosophy of attempting to mimic the original hydrology by means of decentralized micro-management stormwater controls has been found advantageous in site development planning and engineering design to help reduce the negative impacts of additional stormwater runoff created by impervious surfaces and soil compaction.

Low Impact Development (LID) has found straightforward opportunities for application in humid climates where a large portion of the annual rainfall volume comes in relatively small rainfall depths. In arid and semi-arid climates LID encounters several challenges due to frequency and size of storm events that result in long periods of dry weather with a few large precipitation events accounting for most of the annual rainfall volume. Urbanized semi-arid regions experience a significant amount of dry-weather flows in the form of return from excessive irrigation on suburban lawns. Figure 1 shows an example in a rapidly urbanizing rural area in Idaho. These dry-weather flows carry significant amounts of nutrients from household fertilizers, which are discharged to receiving water bodies. These nutrients cause unsightly algal growth sometimes known as “urban slobber,” that result in oxygen depletion due to organic matter decay. These flow rates can constitute a large component of dry-weather flow in urban streams and the nutrient loads are likely to have a negative impact. It should be noted that many urban areas, regardless of climate, have experienced increased dry-weather flows that have been attributed to landscape irrigation and other source associated with “leaky” urban infrastructure.



*Figure 1. Excess irrigation applied to a suburban development in Idaho.*

### **Potential Solutions**

Several municipalities are devoting a great deal of attention to these nuisance flows. For example, the Santa Monica Urban Runoff Recycling Facility (SMURFF) was constructed to treat an average of 500,000 gallons per day of dry weather flow from excess irrigation, as well as spills, on-street car washing, pavement washdown, and construction site runoff. The SMURFF provides a sophisticated treatment train of processes that include screening to remove litter, dissolved air flotation (DAF) to remove oil and grease, sand and grit removal, micro-filtration to reduce turbidity, and ultraviolet (UV) radiation to kill pathogens.

The SMURFF was successfully integrated into a park where the visitors can follow the treatment process. An additional benefit is that the treated effluent can be used for landscape irrigation or toilets flushing.

These end-of-pipe facilities are effective but energy intensive, require dedicated land, and are expensive to build and operate. The necessary resources may not be available in every community that experiences nuisance dry-weather flows. In the absence of institutional enforcement to reduce irrigation excess flow, Low Impact Development retrofits present a viable alternative to mitigate the problems. Dry-weather flow is not the typical LID application but it is compatible with many of the LID's strengths. The flows are small and LID distributed controls can be deployed strategically to capture these flows close to the point where they are generated. The plants in bioretention facilities and bioswales can be

sized to optimize utilization of the excess nutrients. The controls can be blended into existing landscape improving the aesthetics of the site.

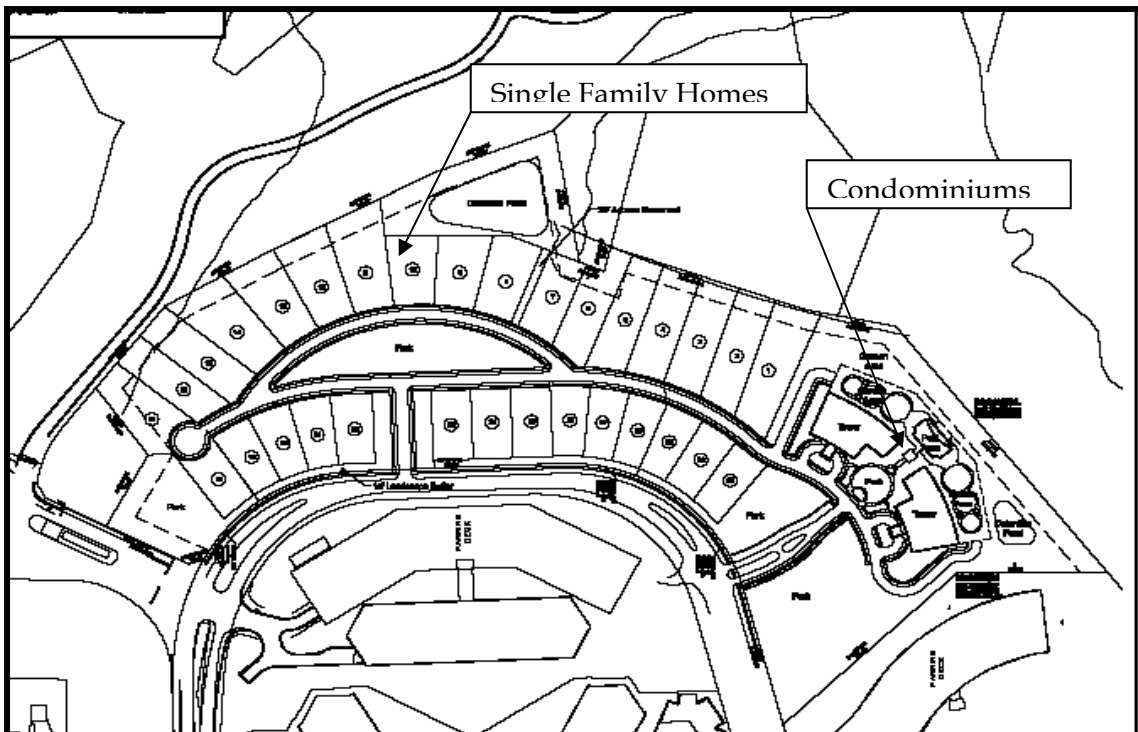
The remainder of this paper explains the application of modeling to explore LID's applicability to this problem.

### Site Selection and Description

The property identified for the case study was a 20-acre site that is slated for development, located in Orange County, California immediately upstream of a river. The development on the property is representative of a typical development and includes:

- Representative mix of land use including commercial, retail, and residential.
- Representative size is similar to other remaining or anticipated development sites.

The proposed development consists of both attached and detached single family residential, and a residential high-rise condominium as shown in Figure 2. Based on the most current layout, there are 31 lots slated for single family homes and two towers with a total of 342 units. Stormwater management for the proposed development will be handled with a curb and gutter system with pipes conveying stormwater to two detention ponds. One pond will handle the stormwater for the single family residential area and one pond will handle the stormwater from the high-rise condominium area. Of the total site area, approximately 3.6 acres would be preserved as natural space plus additional park and green space scattered throughout the development. There is an estimated 6.9 acres of impervious area or a percent imperviousness of approximately 28%.



*Figure 2: Proposed Development*

## **Evaluation Criteria**

The hydrologic cycle describes the full path a drop of water can take when it drops from a rain cloud. For natural, undisturbed areas, the majority of rainfall is intercepted by vegetation or infiltrates into the soil. Once water is infiltrated, it is either used by vegetation through evapotranspiration or flows offsite through subsurface flow. Some of the infiltrated rainfall soaks deeper into the ground recharging the groundwater. A very small percentage, as little as 1%, of rainfall actually leaves an undisturbed site as surface runoff; whereas, surface runoff is drastically increased when a site is developed, increasing to upwards of 25% of the total rainfall. Modifications to landscape through development alter the natural hydrologic cycle, called hydromodification. Basically, hydromodification is a change between the pre-development and post-development runoff conditions in which both the rate of stormwater runoff and overall volume of stormwater runoff are increased. Although peak flows are often controlled by properly sized best management practices (BMPs) widely used today, however, the increase in total volume of stormwater can still cause stream degradation and loss of aquatic habitat.

To minimize the impacts of development, site design should attempt to mimic as closely as possible the pre-development runoff conditions for all storm events. This can be especially beneficial in urbanized semi-arid regions experiencing significant amount of dry-weather flows in the form of return from excessive irrigation on suburban lawns. For this case study, the peak runoff rates for a range of storm events and dry weather flows were examined.

## **LIFE™ Model Application**

### **Model Overview**

CH2M HILL's LIFE™ model was applied to test the performance of LID techniques for different land uses, rainfall patterns and soil characteristics. The LIFE™ model is a physically-based hydrologic and water quality simulation tool that was developed to evaluate the performance of various LID techniques (e.g., bioretention, infiltration systems, rainwater capture/reuse systems, permeable pavement, green roofs, etc). It is well suited to site-level analysis of spatially distributed stormwater source controls (i.e., LID techniques). The LIFE™ model provides a continuous simulation of the runoff, interflow, infiltration, baseflow from a development (or re-development) area given the following inputs:

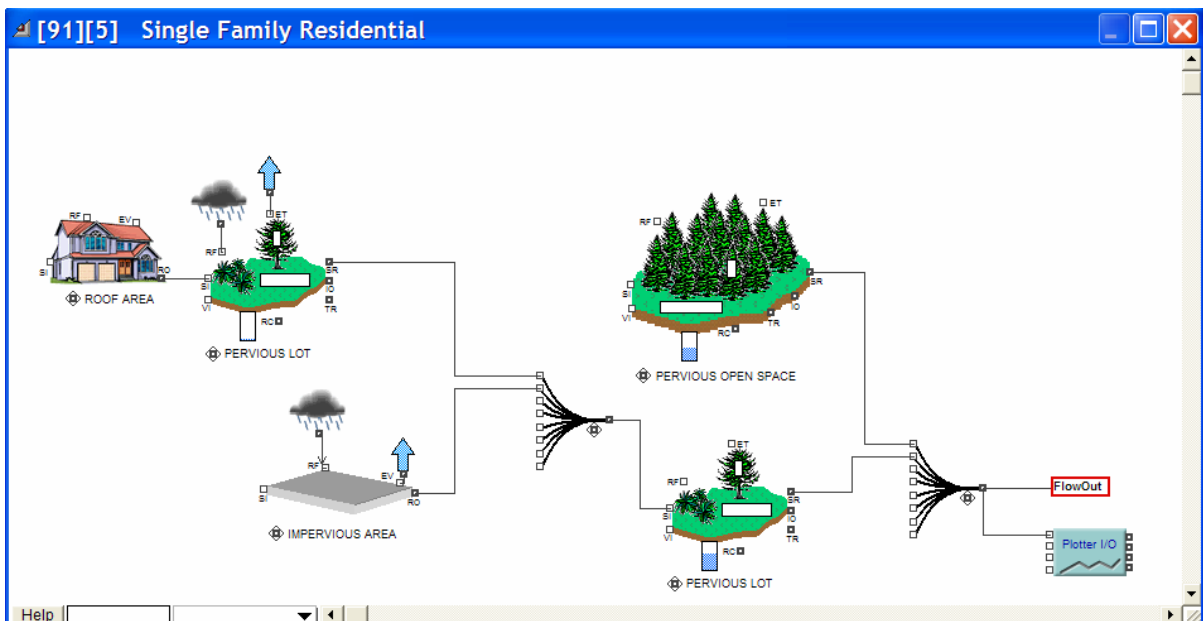
- Continuous rainfall data (typically in time increments of one hour or less) and evapotranspiration data (daily), typically for a time period of one year or more. Evapotranspiration (ET) can also be calculated from temperature data.
- Site design parameters and land cover characteristics for each land use type being modeled (e.g., road width, rooftop coverage, surface parking coverage).
- Extent of source control application (e.g., fractions of road and of building coverage with a certain types of source controls)
- Source control design parameters (e.g. area and depth of infiltration facilities, soil depth for green roofs or absorbent landscaping, volume of rainwater re-use cisterns)
- Surface soil parameters (e.g. maximum water content, vegetation rooting depth). The common soil types in the study area and their relative percentages are:
  - San Emigdio Fine Sandy Loam (80%)

- Metz Loamy Sand (20%)
- Sub-surface soil parameters (e.g. saturated hydraulic conductivity)

### Model Development and Modeling Scenarios

The estimation of the dry weather flows in the form of excess lawn irrigation was estimated based on two sources, lawn watering guidelines for California and the Wetland Capture and Treatment Network (WETCAT) Project for the California Regional Water Quality Board. The lawn watering guidelines, Publication 8044 by the University of California, recommends lawn irrigation of 56 minutes per week for warm season grass types in the winter months provided the sprinkler output is 0.5 inch/hour. This lawn irrigation cycle was modeled as storm events by the LIFE Model. To validate the reasonableness of the resulting dry weather flows generated by the LIFE Model, the WETCAT project was consulted. The Wetland Capture and Treatment Network Project consists of three constructed, multi-purpose wetlands designed to capture and treat low-flow urban runoff from a suburban residential neighborhood in the Aliso Creek watershed, Orange County, California. Dry-weather flow is intercepted before entering the main storm drain, treated by 2.1 acres of constructed and enhanced marsh, and then released into the main pipe and from there downstream to Sulphur Creek and Aliso Creek. The extensive monitoring conducted of dry weather flows by the WETCAT project validated the dry weather flows generated by the LIFE Model.

In order to model the dry weather flow from the sprinkler system, the lawns of residential areas and their adjacent areas such as a driveway were represented in the model as depicted in Figure 3.



*Figure 3: Model representation of the development.*

Further, a 30% over spray onto paved areas was assumed assuming that residents have a tendency to over spray to make sure that their lawn gets the water it needs but they do not worry whether some of the water will spray on non-lawn areas as shown in Figure 1. To account for this, the paved areas near the landscaped areas were broken into two categories: 1) a paved area equal to 30% of the nearby lawn area that receives the irrigation “rain” as if it were lawn 2) the rest of the paved area, which receives no “rain.”

## **Model Results**

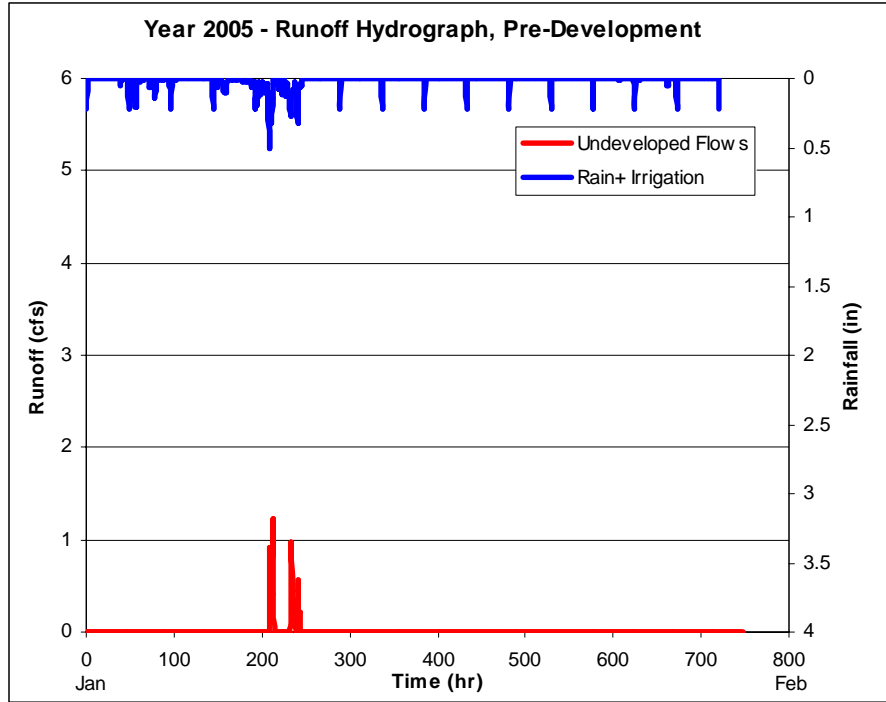
Model scenarios were compared based on the evaluation criteria mentioned above and are summarized in Figures 4 through 8.

As shown in Figure 4, very little runoff is generated in the pre-development scenario. The soils and existing vegetation are able to absorb much of the runoff associated with the storm events and even excess irrigation flows if they were present. As shown in Figure 5, however, the effect of increased runoff is clearly seen in the extended period of runoff compared to the predevelopment condition. During periods with little precipitation, runoff is still generated as a result of dry weather flows. The incorporation of a conventional drainage system consisting of storm drain pipes and detention facilities is beneficial in attenuating the peak flow rates for storm events but does little in reducing the dry weather flows as shown in Figure 6. As mentioned earlier, this could have implications for water quality and the quality of channel substrate material. These dry-weather flows carry significant amounts of nutrients from household fertilizers, which are discharged to receiving water bodies. The result of this input is excessive algae which could colonize the channel substrate material and deplete dissolved oxygen levels.

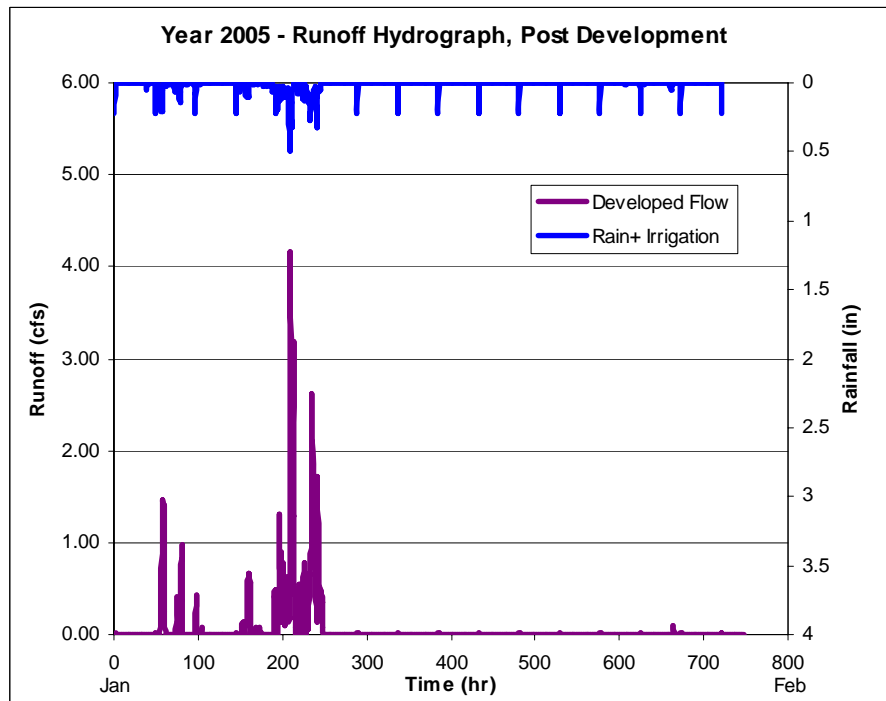
For the LID scenario, as evident in Figure 7, there is essentially no runoff generation from the site for the relatively small storm events. Attenuation of the peak discharge rate and storm runoff volume for the larger events is evident. Dry weather flows in the form of excess lawn irrigation is reduced significantly. It should be noted that the peak attenuation under the LID scenario is somewhat less than with conventional development. However, the LID option provides much better overall controls of the runoff volume, including the nuisance flows. Peak attenuation can be matched by optimizing the size of the LID controls.

## **Conclusions**

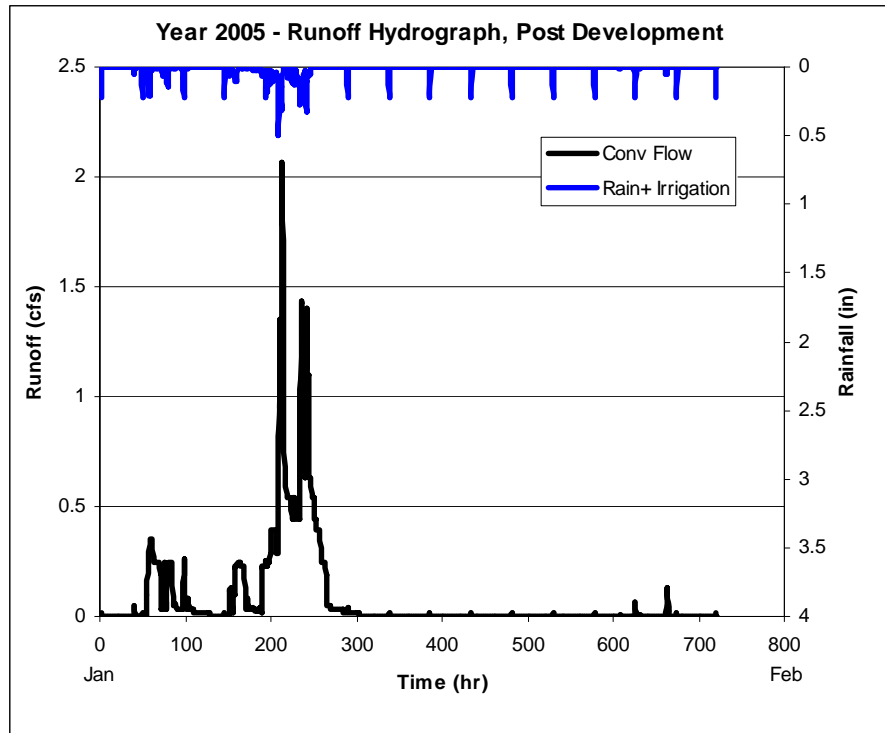
Excess irrigation can be a significant component of dry weather flows in semi arid climates, however, these flows can become a nuisance due to aesthetic concerns and their impact on receiving waterways due to high nutrient loads. Control of these flows aligns well with the principles of LID and the functionality of LID stormwater controls. The LIFE™ model was used to demonstrate that it is feasible to use LID to controls these flows, as well as rainfall runoff, in reducing inputs to surface waters.



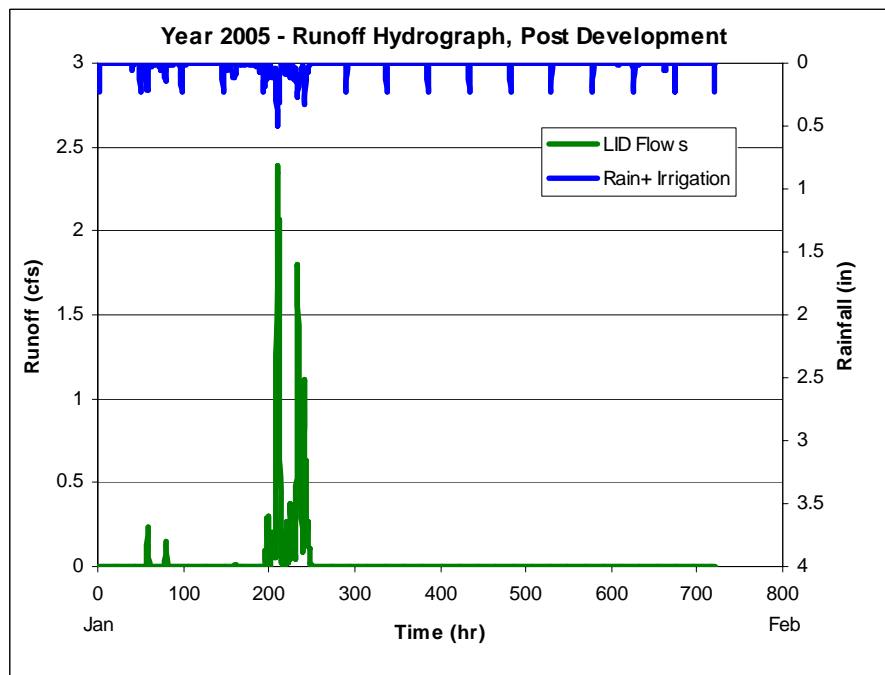
**Figure 4: Runoff Hydrograph for Year 2005 Rainfall Season, Pre-development Condition**



**Figure 5: Runoff Hydrograph for year 2005 Rainfall Season, Post Development without stormwater management.**



**Figure 6: Runoff Hydrograph for Year 2005 Rainfall Season, Post Development with Conventional BMPs**



**Figure 7: Runoff Hydrograph for Year 2005 Rainfall Season, Post Development with LID BMPs.**