Design of Next Generation Sprinkler Head for Curved Landscapes

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Abstract
With growing population and dwindling water sources throughout the U.S., Cities, Counties and Water Agencies are seeking ways to conserve water and reduce surface runoff. This paper will describe the advantages of using a new proposed sprinkler head developed through a partnership between CSU Fullerton and the Bureau of Reclamation. Depending on the degree of curvature of the landscape, existing sprinkler heads spill water onto hardscapes, thus contributing to water wastage and added surface runoff. The benefits of the new sprinkler head are easily quantifiable and the objective is ultimately to provide landscape professionals and homeowners an easy alternative to save water and reduce urban run-off which is impairing several waterways.

Introduction
The motivation of this work is to design a new sprinkler nozzle with multiple orifice openings that can optimally water curved landscapes. Existing sprinkler heads although perform well for regular landscapes, are far from optimal when used across curved landscapes. Depending on the degree of curvature of the landscape, existing sprinklers spill water onto hardscapes (i.e., sidewalks, driveways, roads etc), thus contributing to, water wastage and added surface runoff. The proposed sprinkler nozzle will have inbuilt mechanism that can take into account the curvature of the landscape and thus optimally water the landscape. It will provide a practical approach for efficiently watering curved landscapes. Additionally, an improved sprinkler system can also open new opportunities for improved landscape design. Since urban lifestyle and good landscaping go hand in hand, an offshoot of this work is an enhanced quality of life. With rising water costs and depleting water sources, the proposed sprinkler can benefit both the end users and water management agencies. The target audience that can be benefit from the proposed sprinkler nozzle are water managers, home owners, city planners/decision makers, landscape designers and architects.

According to the U.S. Geological Survey, of the 26 billion gallons of water consumed daily in the United States[1], approximately 30 percent (i.e., 7.8 billion gallons), is spent on outdoor uses. A significant portion on the water is spent in landscaping. It is estimated

[1] W.B. Solley, R.R. Pierce, and H.A. Perlman. 1998. *Estimated Use of Water in the United States in 1995* (USGS Circular 1200). USGS. Reston, VA. p.27.

that a typical suburban lawn consumes 10,000 gallons of water above and beyond rainwater each year[2]. In the U.S., 25% to 33% of the estimated 101 gallons of water per capita consumed daily in single family residences is used to water plants, lawns and gardens[3]. In arid regions like the southwestern United States, that percentage can be as high as 60% to 90%[3,4]. Existing sprinklers although they perform well in the interior regions of any large landscapes, when used in the vicinity of the borders in a curved landscape, they spill water on to its adjacent hardscape (i.e., sidewalk, driveway, roads, et al.) Although estimating the amount of water that is spilled onto driveways/hardscape is a difficult task, it is safe to say that for curved landscapes a certain amount of water does spill on to the hardscape.

Designing an efficient sprinkler nozzle that can take into account the curvature of landscape can contribute to among others (a) water conservation/efficient efficient water use and (b) reduced urban runoff. Figure 1 is a definition sketch to illustrate the performance details of current and proposed sprinkler nozzle head for curved landscapes.

The second order affects of the proposed sprinkler nozzle include

(a) Improved water quality in the water bodies, that otherwise are polluted by the runoff
(b) Enhanced biological integrity and improved ecosystem
(c) Extended life of related infrastructure components

The proposed sprinkler nozzle is a lasting economical solution to an otherwise problem, that has not been addressed satisfactorily until now. With no affective mechanism in place to stop polluted water in storm drains from reaching oceans and other water bodies, the proposed sprinkler can significantly reduce the volume of dry urban runoff.

Performance of Existing Sprinklers for Curved Landscapes

Currently there are many sprinkler heads (both from spray and rotor sprinklers) which can be used for watering regular and irregular landscapes. While the standard spray sprinkler nozzles have many characteristic features, the feature closest to the proposed sprinkler is their ability to water quarter, half and full circle areas, which facilitates directing water to any particular area of interest (i.e., the watering arc can be manipulated from 45^o to 90^o, from 90^o to 180^o etc.). Independent of the degree of water arc, the water spray will still continue to be uniform all across the flow area. Since the flow area will be uniform, the existing sprinklers cannot be optimally used for curved landscapes. Figure 2 illustrates a sample limitation of the existing nozzles.

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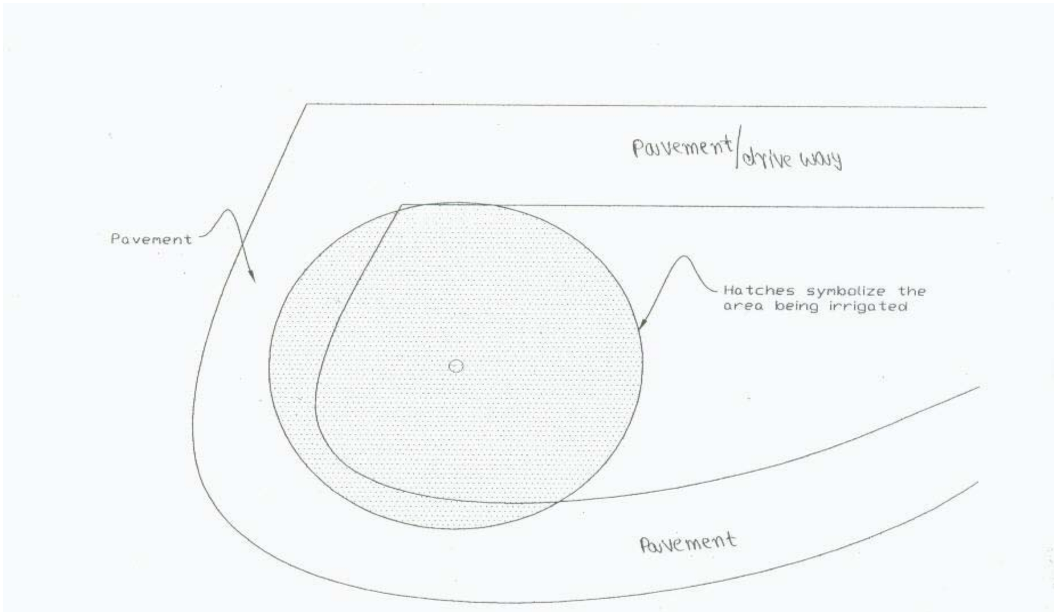
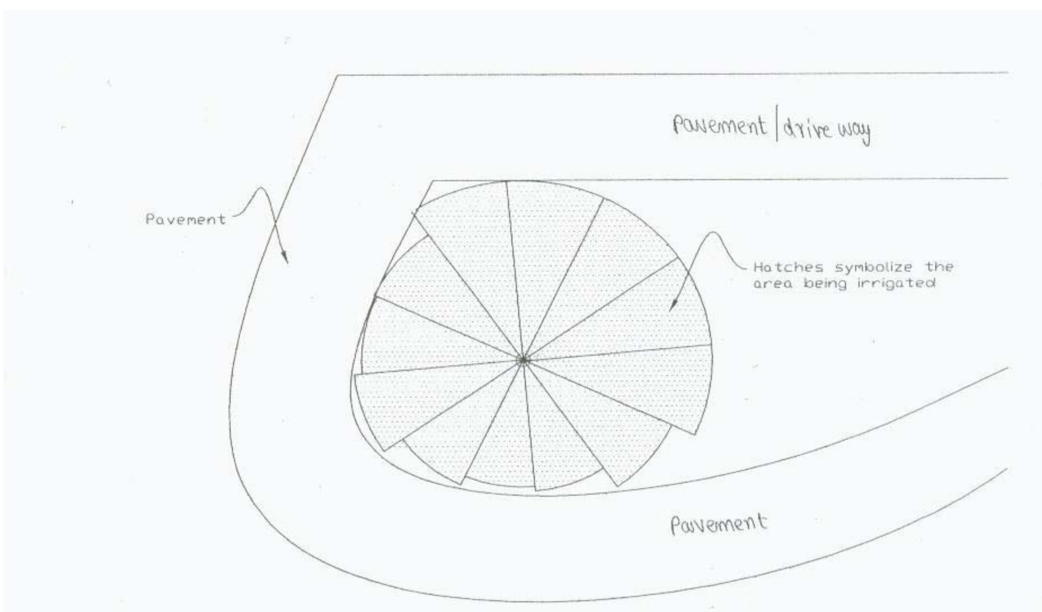
[2] Amy Vickers. 2001. *Handbook of Water Use and Conservation*. WaterPlow Press. Amherst, MA. p. 140.
[3] Kent A. Sovocool and Janet L. Rosales, A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert,[online paper] available from Southern Nevada Water Authority at www.snwa.com/assets/pdf/xeri_study.pdf
[4] Vickers, *Handbook of Water Use and Conservation,* Waterplow Press, ISBN 1-931579-07-5



(a)



(b)

Figure 1. Definition sketch to illustrate the performance details of (a) existing sprinkler head and (b) proposed sprinkler head across curved landscapes (the location of the sprinkler head is identified by o)

An optimal sprinkler for curved/irregular landscape should have a feature in it, by which the radius of flow emanating from each orifice opening can be controlled.

Figure 2. Sample photograph to illustrate the water efficiency wise limitation of standard sprinkler heads for curved and irregular landscapes

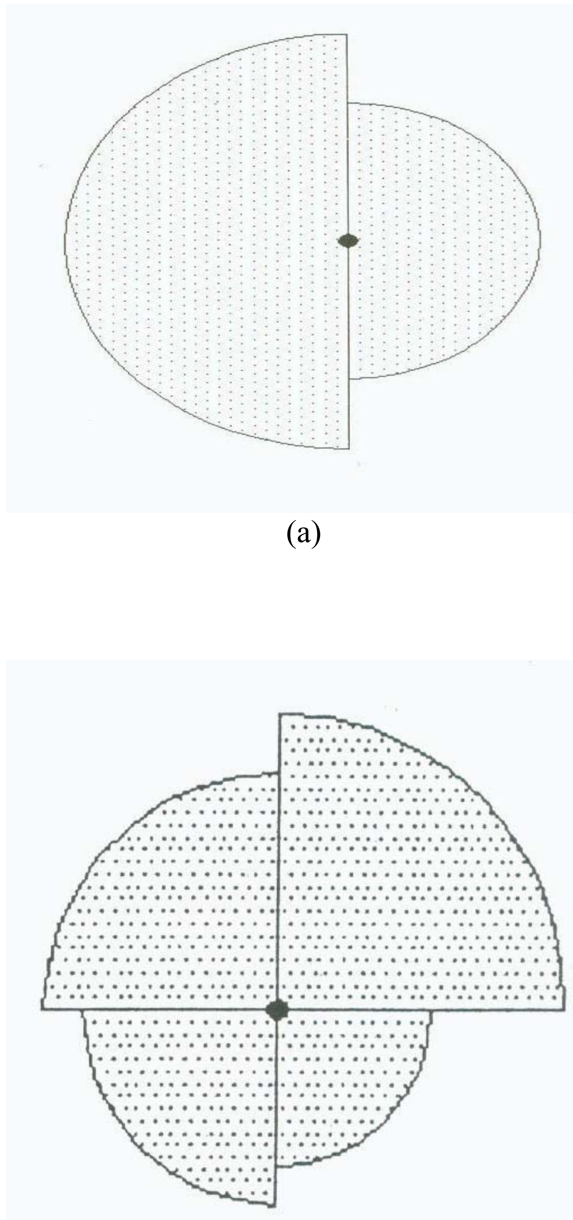
Design Details of the New Sprinkler Nozzle

Since the design aspects of the new nozzle are currently in the process of being patented, the authors are not sharing those particular details in this paper. Interested audience can directly correspond with the authors, so as to get a copy of the drawings.

The features in this new sprinkler nozzle are

- The nozzle can have multiple orifices
- The radius of the water arc emanating from each orifice opening can be adjusted
- The spraying pattern from each orifice is uniform, and this is independent of the radius of water arc from that orifice
- For landscapes with steep curvature, a nozzle with multiple orifices can be chosen to water the whole landscape area efficiently
- For using the sprinkler head, no additional learning/training is required from the end user
- No additional investment is needed from the end user to install the new sprinkler head into their landscape
- It can be used for both pop-up style sprinklers and shrub style sprinklers

Sample performance aspects of the nozzles with two and four orifices is shown in Figure 3.



(a)

(b)

Figure 3. (a) Nozzle with two orifices spraying water across two radii (b) Nozzle with four orifices spraying water across four radii

Experimental Test Site for Measuring the Performance Details
The reliability of the newly designed sprinkler head is being tested for a sample landscape, shown in Figure 12. The width of this curved landscape (located in the campus of CSU, Fullerton) varies from 4 ft to 16 ft, across a length of 20 ft. Along the four sides, the landscape is surrounded by walkways which are frequently used by the students. Figure 12 captures the salient details of this test site. Sections AA and BB, at which the performance tests have been illustrated later on are identified in Figure 12. While the width of the landscape at AA is 4 ft, the width at BB is 12 ft. Our idea in choosing this site for testing the sprinkler head is twofold: (a) It closely resembles the curved landscapes in real word and (b) It facilitates in an unbiased testing of the sprinkler heads.

The orifice with two nozzles has been used in these tests. One of the orifice openings was closed and the flow occurred through the other orifice opening. The pipe assembly was placed along the side CC (see Figure 12) and water was allowed to spray through the orifice opening facing the landscape. This nozzle has been tested across 9 sections, the width across which varied from 4ft to 12 ft. The trend of the results at the two end sections (i.e. AA and BB) are presented herein. The idea was to adjust the flow controlling screw of the orifice opening and let water spray to a distance approximately equal to the width of the section. Photographs were taken at the end points for both dry and wet time periods. The dry photographs were used as bench mark data for comparison purposes.

Figure 13 (a) illustrates the profile of the section (section BB in Figure 12), the width of which is equal to 12 ft. On the left side, the pipe assembly is present. Figure 13(b) is the zoom view of the end point, under dry conditions. Figure 13(c) is the zoom view at the same end point, after the sprinkler is switched on. As evident for this water pressure and for flow controlling screw location, the radius of the water is about 13 ft. Figure 13(d) illustrates that the flow pattern is uniform at the orifice opening.

We have then taken the pipe assembly to section BB (see Figure 12), the width of which is equal to 4 ft. Figure 14(a) is a zoom view of the end point under dry conditions. The width of the section is indicated herein. Figure 14(b) is the corresponding view after the sprinkler is switched on. The flow adjustment screw has been adjusted to ensure that the flow through the orifice opening is reduced. This figure indicates, that the radius of water arc is about 4ft. The width of the water arc was observed to be uniform all across its radius.

When Figures 13 and 14 are seen together, the following conclusions can be arrived at:

- By adjusting the position of the flow adjustment screw, the amount of flow and hence the radius of water arc from the orifice opening can be changed.
- The end locations of the flow adjustment screw can either completely shutoff the flow from the orifice or allow a maximum flow rate from the orifice. These end conditions translate to either zero water radius or maximum water radius[5].
- The water spray pattern from the orifice opening is uniform and this is independent on the location of flow adjustment screw.
- The flow adjustment screw facilitates an accurate control of the radius of the water arc.

Table 1 documents the affect of the flow adjustment screw (in terms of the number of revolutions) on the maximum distance over which water can be sprayed for that particular nozzle

[5] The maximum radius of water arc depends on the water pressure in the pipe.

opening. A zero revolution implies that the nozzle opening is completely shutoff. At the end of four revolutions, the discharge in the nozzle opening is maximum and thus the distance of the ??

Table 1. Effect of flow adjustment screw on the maximum distance of the water spray

Number of revolutions	Maximum distance over which water column sprays (in ft)
0	0
0.5	1.6
1	3.6
1.5	5.1
2	7.2
2.5	8.4
3	10.2
3.5	12
4	12.9

(a)

(b)

Figure 12. Test site over which the performance data is being gathered [(a) normal view, (b) zoom view which captures the minimum width of the test site]

(a)

(b)

Figure 13. Performance details of the sprinkler nozzle for the 12 ft width portion of landscape [(a) zoom view of the end point under dry conditions (b) zoom view of the end point under wet conditions]

(a)

(b)

Figure 14. Performance details of the sprinkler nozzle for the 4 ft width portion of landscape [zoom view of the end point under (a) dry conditions (b) wet conditions]

It is expected that this innovative sprinkler nozzle will be a welcomed addition to the options of nozzles, sprinklers and other irrigation hardware available on the market today. Although there are many more advanced irrigation technologies on the market, often it is the low tech options that find its way into consumers' yards. This new sprinkler nozzle will enable those professionals and homeowners concerned with a healthy landscape, save water and reduce non-point source pollution without compromising their aesthetic values.