Irrigation Runoff from Urban Turf and Landscape

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Abstract:
Irrigation runoff was measured from a turf plot with 8 % slope on a loamy sand soil using rotor sprinklers. Moisture levels in the root zone before irrigation and wind direction during irrigation both affect the volume of runoff. Turf cultural practices such as core aerification of the soil increased infiltration and decreased the volume of runoff. Prediction of the maximum irrigation runtime by the equation developed by Hung was longer than the actual time to the beginning runoff. The amount of fertilizer constituents in the runoff was measured. The research protocol including experimental design, equipment, and procedures to collect and quantify irrigation runoff from turf on slopes will be used to continue research in this area.

Introduction:
Runoff from urban landscapes in California has at least two areas of regulatory interest. The first is winter storm water runoff that is channeled to rivers and coastal waters. Runoff quantity, peak flows, and water quality from winter rains are important in watershed management. Urban runoff is related to infiltration; hardscapes such as streets, parking lots, buildings decrease water infiltration resulting in potential of more runoff. Landscape areas serve as infiltration areas and can attenuate peak flows.

A second area of regulatory interest for runoff from landscapes is runoff during the dry weather irrigation season. These surface flows, generally labeled nuisance flows, occur during the March through November irrigation season in Southern California. The quantity of runoff in an ideal landscape irrigation world should be zero. However, the norm for most urban communities with existing landscape is that there is significant summer runoff unto hardscapes, gutters and storm drains that can degrade rivers and coastal waters. It is often assumed that chemical applications of fertilizers, herbicides on landscapes and grass clipping contribute to pollution in urban runoff.

The focus of this research is the second area – dry season irrigation runoff. With Southern California water supplies stressed, any runoff from landscapes is considered a waste of this limited resource. This research will correlate the quantity and quality of runoff from landscapes with respect irrigation runtime, wind, and soil moisture. A theoretical equation proposed by Hung (Hung 1995) to predict the maximum sprinkler run time without runoff for sprinkler irrigation is also of interest. Therefore, time was recorded when ponding and runoff from the plot to correlate with the predicted maximum run time.

Recent studies completed or in progress include a residential runoff reduction study by the Municipal Water District of Orange County (MODOC), which showed a 49% reduction results in watershed runoff with the installation of ET controllers on residential sites (Anonymous, 2004). The city of Tustin and the Irvine Ranch Water District (2002-03) installed a WICK irrigation system on a large street median, which virtually eliminated runoff that had previously occurred at the same site with sprinkler irrigation (www.irwd.gov 2004) The research we are proposing would complement current work.

The implementation of Phase II of the Clean Water Act will impact landscape irrigation. The California State Water Resources Control Board has identified Urban Management Measures (www.swrcb.ca.gov/stormwtr/). Municipalities are required to develop plans to address non point source pollution of "sensitive waters". The initial focus in some areas appears to be on identifiable sources such as nursery and greenhouse operations in areas such as San Diego (private communication Jim Brazie, Hydroscape Products).

Dry weather urban runoff in the City of Santa Monica required the construction of SMURF, a nine million dollar project to intercept surface water running into the Bay. The runoff volume of 500,000 gal per day (1.5 acre –foot/day) is treated for reuse. The city has recently passed an ordinance to prohibit runoff from landscapes.

It is clear from the above examples that in California, water districts, and the agricultural enterprises near urban areas have a stake in urban runoff. Horticultural enterprises that service the urban landscape markets will be affected by efforts to limit landscape areas and irrigation water availability that may be driven in part by irrigation runoff management issues. Water management for urban landscapes can be improved through BMP's that are supported by applied scientific studies.

Procedures:
An existing 50 ft by 50 ft plot of hybrid GN-1 bermudagrass turf maintained under golf course fairway management on the Cal Poly University Pomona campus was used for these tests. Rotor sprinklers with nozzles for 50 foot radius at 50 psi operated at each corner of the plot. Catch Can tests (IA Procedures) conducted to determine distribution uniformity showed the system had a low quarter distribution uniformity of 65% and a precipitation rate of 1.2 inches per hour. Seven WaterMark moisture sensors were installed at 4 locations within the plot at 4 and 8 inch depths. The moisture sensors recorded the soil matric potential at 5 minute intervals before and after each irrigation event.

The plot had an average slope of 8% in the general direction where the runoff collection containers were located. Runoff from the low side of the rectangular plot was collected in two components, 1. surface flow off the low end of the plot, 2. wind borne water carried past the low end of the plot. These two sources of urban runoff are commonly experienced where irrigation water runs over the curb as surface flow and wind carries water from sprinklers beyond landscape borders; both sources of water combine to form runoff into the storm water system. Two troughs made of rain gutters were installed at the lower end of the plot. The first trough collected surface runoff from low edge of the plot; the second trough collected overspray or wind drift at the low edge of the plot. A four foot high plastic barrier about 2 feet beyond the lower end of the plot, collected the wind drift and directed that water into the second trough. A metal deflector, mounted above the first trough, prevented the wind drift from falling into the surface runoff trough, and directed that water into the surface runoff trough. Catch cans were also positioned outside the plot to monitor wind drift on each side.

50' x 50' BermudaTurf Plot

Figure 1. Layout of the irrigation runoff plots on a GN-1 hybrid bermudagrass turf with an 8% slope

A normal runtime for this plot with loamy sand soil and an 8 inch root zone was 25 minutes to bring the root zone from 50% depletion to field capacity. The irrigation runtime was set for 60 minutes to insure runoff so that the beginning of actual runoff could be compared with predicted maximum irrigation runtime without runoff. Runtime was reduced to 40 minutes for several of the tests because the volume of runoff exceeded the runoff collection device capacity. The runtime for these irrigation events will be referred to in the rest of this report as the "extended runtime".

Objectives and Results:

Objective 1. Does the maximum runtime equation accurately predict the sprinkler runtime to prevent runoff from turf on slopes?

The following equation (Hung 1995) predicts the maximum irrigation runtime without runoff.

$$T_{max} = (1/Pb)\ \{f_o - P + f_c\{\ln(f_o - f_c)/(P - f_c)]\}$$

Where; T_{max} = maximum irrigation runtime without runoff(hours)

P = average sprinkler precipitation rate

b = Horton's constant

f_o = infiltration rate at the start or at time = 0

f_c = basic infiltration rate or saturated infiltration rate = constant

There is a graphical method to convert T_{max} for 0% slope to slopes up to 20%.

Results:
The results are based on nine irrigation events on one plot. The time interval from the beginning of an irrigation to the time that ponding of water was visible at selected locations in the plot was recorded. This time for ponding to occur was compared with T_{max} as determined by the above equation. Using the equation for a sandy loam soil with a Horton constant of 2.48, for a 6-8% slope resulted in a calculated maximum runtime approximately 100 minutes. The results of a one double ring infiltrometer test conducted on this plot had a Horton's constant of 5.89. Using this equation with this Horton's constant, the maximum irrigation runtime without runoff changed to 42 minutes. The actual times for ponding of water to be visible ranged from 15 – 29 minutes with a mean of 20 minutes. These results suggest that the Horton's equation over estimates the time before runoff would begin.

Figure 1 suggests that the initial soil moisture affects the time when ponding of water was visible, as would be expected.

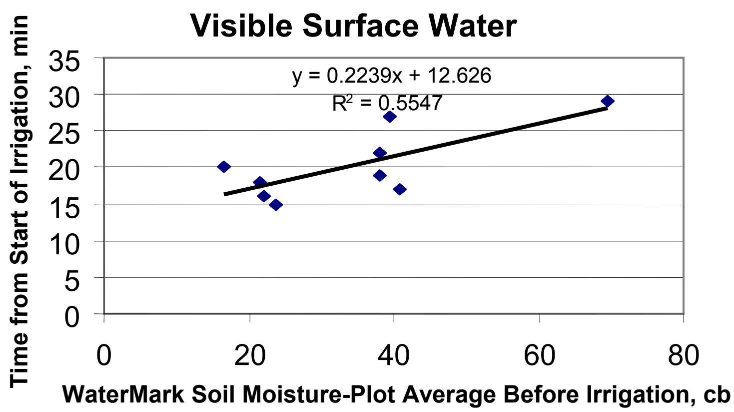

Figure 1. Effect of soil moisture on the time when first visible runoff was observed.

<u>Objectives 2 and 3.</u>
2. What is the relationship between extended irrigation runtimes and volume of runoff surface off the edge of the landscape and wind drift of water over the edge of the landscape?
3. What effect does turf cultural practices such core aeration of turf with top dressing of sand have on volume of irrigation runoff?

Results:

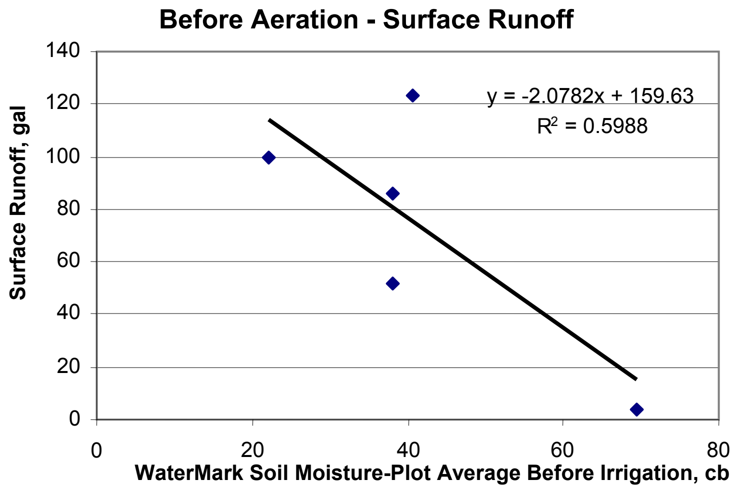

Figure 2. Surface runoff for the plot in the untreated condition (before core aeration) with extended irrigation runtime.

Irrigation runoff was collected as two components: surface runoff and wind drift. The mean moisture content for the seven moisture sensors ranged from 22 – 70 cb. Soil matric potential of 40 cb for loamy sand soil is near 50% of plant available water. The least runoff volume (4 gal) occurred, as expected, for the irrigation event when the soil moisture was lowest before irrigation.

Wind direction and wind speed also influenced the surface runoff; this will be discussed later. The highest runoff volumes appear to depend on both wind direction and soil moisture before beginning of irrigation.

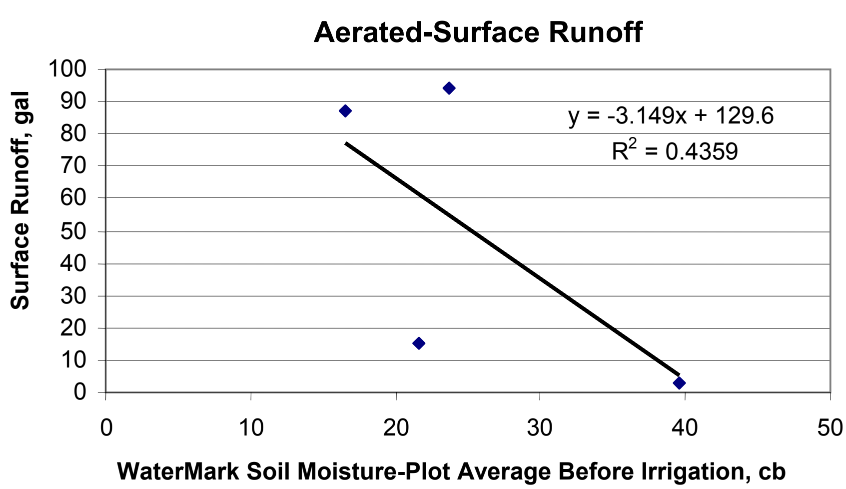

Figure 3. Surface runoff for four irrigation events after core aeration and top dressing with sand.

The volume of surface runoff was compared for four irrigations for both the non-aerated and aerated plot with similar initial moisture contents. The non-aerated plot had mean matric potential before the irrigation events of 35 cb that resulted in a mean surface runoff of 73 gallons and the aerated plot with mean moisture of 26 cb had a mean surface runoff of 50 gallons. This would suggest aeration does decrease runoff. Additional aspects of this study are discussed in another publication (Mitra et al., 2006).

Runoff as percent of total amount of applied irrigation water, when combining data from both treated and untreated tests, ranged from 0.4 to 9.6% with mean of 5.3%. It is important to note that the runtime for these irrigation events were approximately twice the normal runtime to fill the root zone.

Overspray due to wind drift

It is well known that wind distorts sprinkler distribution patterns and contributes to runoff when landscapes border a hard surface area. The hourly wind speed during the irrigation events ranged from 2.9 – 4.2 mph, affecting the radius of throw of the sprinklers. Wind direction appeared to have a more pronounced effect than wind speed on this component of runoff. Runoff was collected from only one side of the plot. Therefore, when the wind direction was perpendicular and in the direction toward the runoff collection device (approximately 340^{o}), the volume of runoff increased (Figure 4). There was more overspray anytime the wind direction was in range from 250 – 360 degrees. The raised plastic barrier deflected this water into the runoff collection system for measurement.

When the wind was in the range of 30 – 250 degrees, there was wind drift off one or more of the other three edges of the rectangular plot. A sampling of overspray measured by catch cans stationed around the other three sides of the plot suggest a similar volume of water drifted off the plot in the other directions. This water could become runoff if there was hardscape on those sides as well, if the other sides had additional landscape that water may not become runoff. The volume of overspray included in the data was the water collected at the lower edge of the plot.

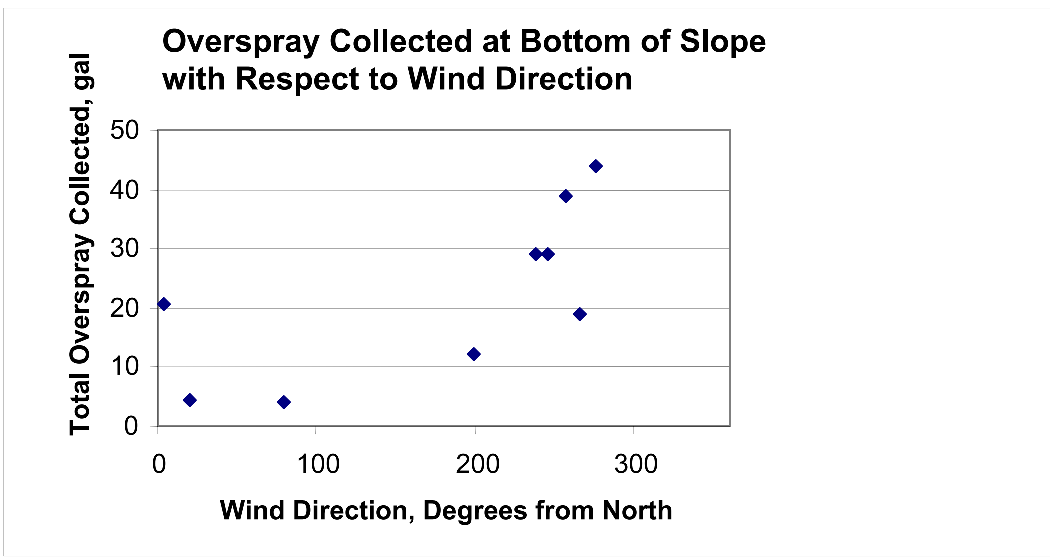

Figure 4. Wind at 340 degrees would direct water into the overspray collection device.

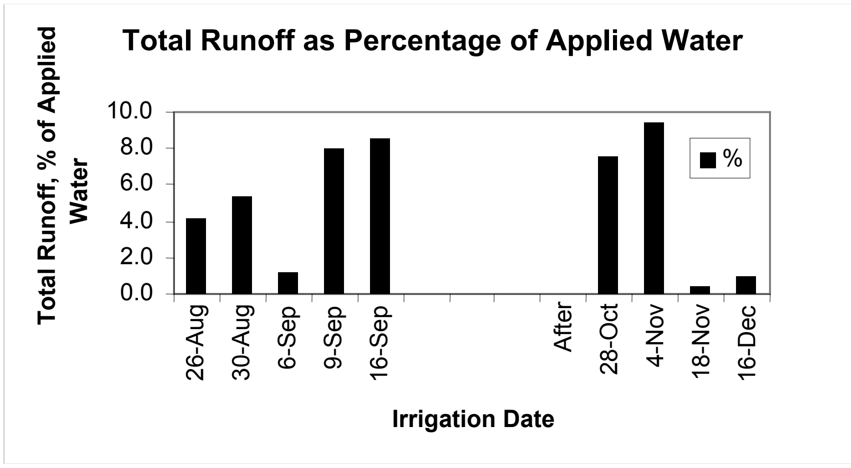

Figure 5. Total runoff for each test date with extended runtime.

The total runoff collected at the lower edge of plot ranged 0.4 to 9.5 % of the applied water (Figure 5).

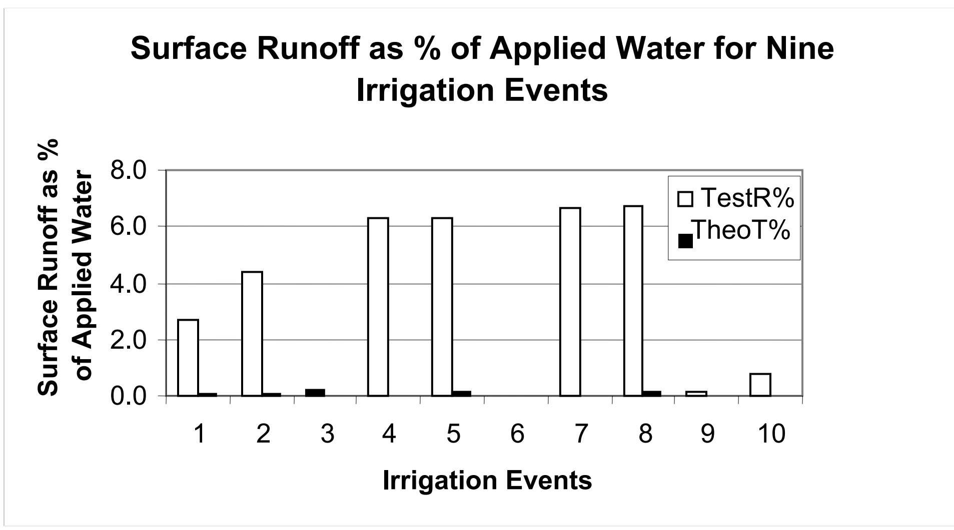

Figure 6. Surface runoff for the nine test with extended runtime (TestR%) and estimated surface runoff if system had run for a theoretical runtime (TheoT%) to fill the root zone.

Figure 6 compares the surface runoff for each test runtime and the estimated runoff if the system had been run for the theoretical runtime of 25 minutes. Runtimes could be adjusted for each irrigation event to take into consideration the initial soil moisture conditions, but for the purposes of this comparison 25 minutes in used for all irrigation events. It is evident that surface runoff was near zero for all events with a runtime of 25 minutes (Figure 6). Therefore, proper scheduling of runtime would minimize most surface runoff.

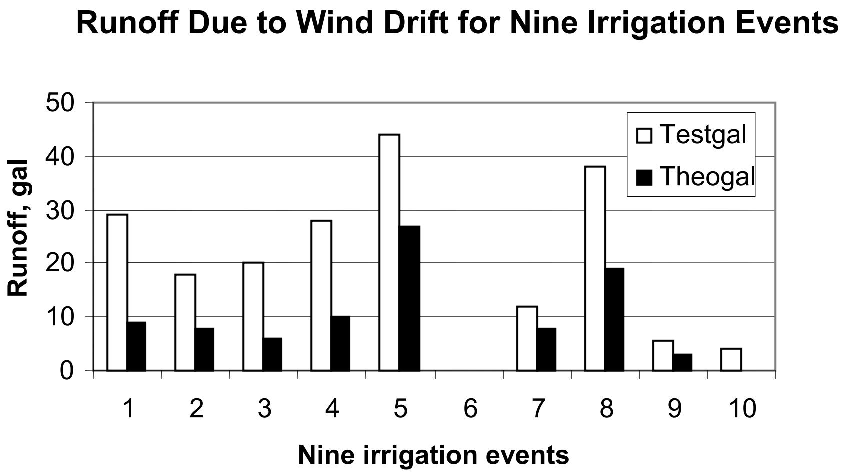

Figure 7. Actual volume of wind drift runoff for each test with extended runtime (Testgal) and estimated wind drift (Theogal) runoff if system had run for theoretical runtime to fill the root zone.

The runoff volume due to wind drift is obviously greater for the extended test runtimes than the shorter theoretical runtimes. Runoff volume due to wind drift with the shorter theoretical runtimes ranged from 0 – 27 gallons with a mean of 10 gallons.

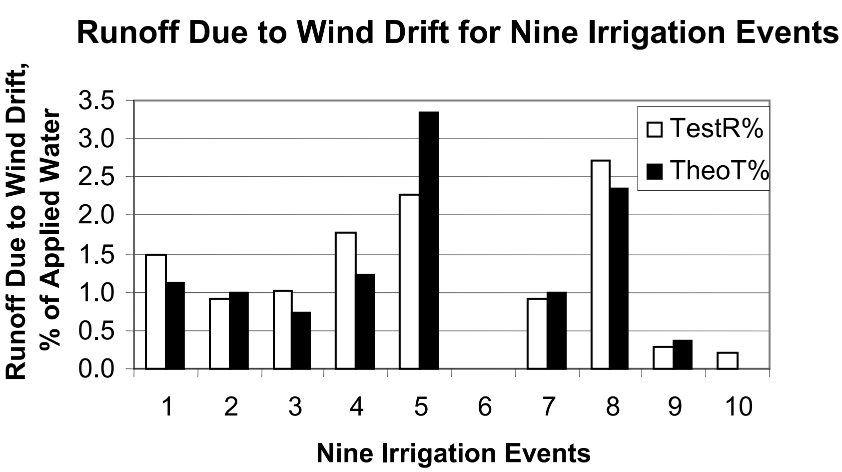

Figure 8. Actual wind drift runoff for each test with extended runtime (TestR%) and estimated wind drift (TheoT%) runoff as percentage of applied water.

Runoff due to wind drift, as percent of applied water, was greater for the shorter theoretical runtime greater for some irrigation events (Figure 8). Overspray runoff data as percentage of applied irrigation water may assist in estimation of potential runoff from irrigated landscape sites where volume of water applied by sprinklers adjacent to hardscapes is measured by meters.

Objective 4.
What is the chemical loading of the runoff after a standard application of fertilizer or herbicide?

Fertilizer (22-4-4 at lb/1000ft^2) was applied one day before one irrigation event. Water sample 2, which had the highest total N, was mixture of surface flow and some subsurface flow. The amount of fertilizer peaked at 56 minutes, and decreased at 69 minutes which was the end of the runoff that occurred. Runoff water had much higher concentrations of ammonium nitrogen and total N than the recycled water used for irrigation.

		Ammonium Nitrogen	**Total N**
Sample	**Sample Description**	**ppm**	**ppm**
1	Irrigation Water Source	0.0319	5.6419
2	Surface/Subsurface(Pit) runoff 45 minutes after begin of irrigation	41.5	131.5
3	Surface runoff 54 minutes after begin of irrigation	10.7	51.5
4	Surface runoff 56 minutes after begin of irrigation	48.8	114.2
5	Surface runoff 69 minutes after begin of irrigation	38.6	99.7
6	Surface runoff 69 minutes after begin of irrigation	35.4	98.4

Summary and Discussion:
1. The current form of the maximum runtime equation overestimated the time for runoff for this type of soil, slope and landscape. Development of Horton's constants for a range of landscape soil conditions would assist in more accurate estimations of maximum runtimes.
2. Soil moisture before irrigation and wind direction both affect the total runoff. Sensor technology could measure soil moisture and wind direction and adjust irrigation schedules accordingly.
3. The mean volume of runoff was 101 gallons for the non aerated plot and 64 gallon for the aerated plot. This runoff was off the lower edge of a turf plot with an 8 % slope.
4. Proper scheduling would have reduced total runoff from mean of 5.1% of applied water with extended runtime to an estimated 1.3%..
5. Proper scheduling would have reduced surface runoff from mean of 3.8% of applied water with extended runtime to an estimated 0.1% or less.
6. Proper runtime would decrease wind overspray runoff slightly from 1.3% to 1.2%.
7. Methods and equipment was developed to collect and quantify irrigation runoff from a plot.

References:
1. Anonymous. 2004. The Residential Runoff Study. Municipal Water District of Orange County and Irvine Ranch Water District. www.mwdoc.com/WaterUse/R3%20PDFs/R3%20Chapters%20&%20Appendix.pdf. Accessed October 2004
2. Anonymous. Water Quality Control Board. Clean Water Act. www.swrcb.ca.gov/stormwb/. Accessed October. 2004.
3. Brady, N. C. and R. R. Well. 2002 The Nature and Properties of Soils. 13 ed. Prentice Hall

4. Hung, J.Y. T., and A.M. Arturo. 1995 Maximum Sprinkler Irrigation Runtime Without Runoff. Proceeding The Irrigation Association's International Exposition and Technical Conference.
5. Hung, J. Y. T. and A. Krinik. 1995 Maximum Runtime For Sprinkler Irrigation. The 5th International Microirrigation congress Proceedings
6. Hung, J.Y. T. 1997 Sprinkler Soaking Time Between First and Second Irrigation Cycles Without Runoff. Proceeding The Irrigation Association's International Exposition and Technical Conference.
7. Irvine Ranch Water District, 2004. *Landscape & Agricultural Conservation.* Irvine, California. Available :Http://www.irwd.gov. Accessed October 2004.
8. Mitra, S., E. Vis, R. Kumar, R. Plumb, and M. Fam. 2006. Wetting agent and cultural practices increase infiltration and reduce runoff losses of irrigation water. Biologia. 118-122.