Field Study of Uniformity Improvements from Multi-Stream Rotational Spray Heads and Associated Products

Preliminary Results

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10/21/2009

Abstract

Multi-Stream Rotational Spray Heads (MSRSHs) both alone and in combination with other products may offer significant improvements in Lower Quarter Distribution Uniformity (DU_{LQ}). In tentative results from an ongoing study, the authors report that for 97 stations at single-family residences in Southern Nevada, retrofitting traditional fixed pop-up sprays with MSRSHs improved uniformity by 0.18, a relative percent difference (improvement) of 45%.

Additional products tested included a non-rotating, oscillating sprayhead (where a DU_{LQ} improvement of 0.18 was also observed) and in-stem flow control (where an improvement of 0.08 was observed). Combined products stratifications were performed as well with results included below. For all 185 sites covered in this study to date, the DU_{LQ} improvement was 0.16 (relative improvement of 40%).

The results suggest that all the technologies tested do improve DU and in every comparison the results demonstrate statistically significant improvement versus traditional pop-ups. The extent to which water conservation, the ultimate goal for utilities, is practically realized when these improvements are combined with homeowner watering behaviors is still being evaluated at this time.

Introduction

Multi-Stream Rotational Spray Heads (MSRSHs) offer the promise of significant improvements in distribution uniformity and even water savings versus traditional pop-up sprinklers in retrofit applications (Solomon et. al., 2006). Claims of such improvements are invoked because it is believed that such devices are capable of delivering superior uniformity of water application coverage as evidenced by an increase in Lower Quarter Distribution Uniformity (DU_{LQ}) owing to a better

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coverage pattern and a lower application rate. Savings should thus be obtained providing the irrigation schedule is appropriately adjusted to the improvements in the system after retrofits.

There are additional types of products that may lower application and increase uniformity. Some of these, like pressure or flow control, may work in concert with MSRSHs, or function independently to improve distribution uniformity. Some take entirely different approaches to improving uniformity, such as not utilizing a rotational concept at all.

This manuscript covers preliminary results (i.e. after 185 stations thus far completed) from a research study conducted by the Southern Nevada Water Authority (SNWA) that is designed to ultimately quantify the local savings potential of these devices as used in retrofit projects for the single-family residential sector. The preliminary results are expressed principally in terms of change in DU_{LQ} after installation. It is the authors' intent that this preliminary report provide the reader with background to facilitate further discussion and review of the work.

This is not a final or draft final report. The final manuscript will include an even more expansive set of stations and analyses of practical water savings obtained when the behavioral element is considered, recognizing it will take more than a year after installations are completed to effectively evaluate this.

Methods

Interested irrigation component manufactures agreed to provide product to SNWA for purposes of this research study in sufficient quantities that valid statistical testing could be performed for changes in mean DU_{LQ}. SNWA conducted recruitment to the study by way of public messaging, including a web-based sign-up process. More than 450 people rapidly responded for the roughly 200 slots available and were placed on a waiting list before SNWA ended the recruitment. The components evaluated included:

- **Hunter MP Rotators** (predominantly MP 1000s) – a multi-stream rotational spray head.
- **Rain Bird Rotary Nozzles** - a multi-stream rotational spray nozzle.
- **Toro Precision Series Nozzles** – an oscillating-stream spray nozzle.
- **Little Valves** – a user-variable replacement pop-up stem flow reducer (sometimes this product was used in combination with others in specified stratifications).

The research also involves additional stratifications for pressure (including in-head pressure reduction technologies), though these are not addressed in this

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manuscript. While most of the product was donated to the study, SNWA also purchased product, especially to assist in installations such as tools, risers, fittings, etc.

It was communicated to prospective study applicants that in order to qualify a residence needed to have at least 25% of the landscapeable area as turfgrass (this was to assist in successfully being able to partition turf irrigation from future meter data), a working in-ground irrigation system, turf landscaping in decent health, and the participant had to agree to a Participant Agreement governing the terms of the study. The Agreement stipulated among other things that the participant agreed to the installation of product by SNWA staff, that they agreed to maintain their landscape during the study, respond to surveys and requests for follow-up visits, and other reasonable provisions. After installations initiated, SNWA was compelled to also limit participation to properties where spray was not in major ways obstructed (such as by trampolines and the like), where brass heads were not prevalent (the shallow depth associated with these precluded installations of many of the technologies), or where there were other practical concerns. Qualified participants were referred to a trained SNWA team for scheduling of installations.

Pre-installation data collection consisted of recording data about the irrigation controller (make, model, station specific settings, etc.), identifying and documenting turf areas of the landscape, noting slope, and mapping out catchments locations, conducting station pressure and flow tests, and conducting an Irrigation Association (IA) style audit (Irrigation Association 2007, 2009). In some situations where stations were immediately adjacent each other, the stations were effectively treated as a common station for purposes of conducting the audit. In situations where the wind exceeded validity thresholds, the audit and further work had to be rescheduled. Catchments' collection volumes were determined and individually recorded by pouring collected water into a graduated cylinder.

Installation proceeded with retrofit of the heads per the respective technology employed and group assignment. In many cases for practical reasons the heads also needed to be changed out or even moved slightly to accommodate the new technology. Also, there were a significant number of cases in which the throw of water was different post-installation and thus often heads were capped off as no longer necessary. While the stratifications generally determined installed product selections, often the distinct nature of a site (pressure, spacing, etc.) also played a role in what technology was selected for use.

Post-installation procedures began with a check of wind speed (again, if outside the threshold, the audit was postponed). This was followed by a repeat of the audit. Staff were careful to place catchments back in their original mapped

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locations from the first audit. Root depth was checked as well as the new station water pressure and flow rates.

On-site calculations involved using the catchments' volumes to calculate precipitation rates and DU_{LQ} and to use this to calculate initial runtimes and schedules for residents in a manner analogous to that recommend by the IA as per Certified Landscape Irrigation Auditor (CLIA) training (Irrigation Association, 2009). This schedule was shared with the residents with the caveat that ultimately they might have to deviate from this if they felt conditions dictated adjustments. The residents also filled out a survey covering demographics and other potentially important variables..

Data Analyses and Comparisons

In the office, all data was input to a master database for purposes of the analyses conducted herein and the additional work to come. For purposes of this manuscript, per station audit data was assembled for all stations collected at the time of analyses. Descriptive statistics were collected for the entire set and for each grouping of technologies. The specific groupings and sample sizes analyzed to date were:

- **All Retrofits (*185 stations*)**
- **Hunter MP Rotators (*57 stations*)**
- **Hunter MP Rotators with Little Valves (*26 stations*)**
- **Rain Bird Rotary Nozzles (*40 stations*)**
- **Rain Bird Rotary Nozzles with Little Valves (*25 stations*)**
- **Toro Precision Series (*17 stations*)**
- **Little Valves with Existing Components (*20 stations*)**
- **All Multi-Stream Rotational Spray Heads (*97 stations*)**

Pre- and post-installation DU_{LQ} measures comparisons were conducted with means. For these tests, standard *T-tests for Dependent Samples* were used to determine if post-installation means were statistically different from pre-installation values. Means testing for inter-group differences in DU_{LQ} were performed using tests appropriate for unequal sample group sizes (*Honest Significant Difference for Unequal N*). In both sets of tests typical default critical levels for accepting means as statistically different.

Results

Entire Sample Results

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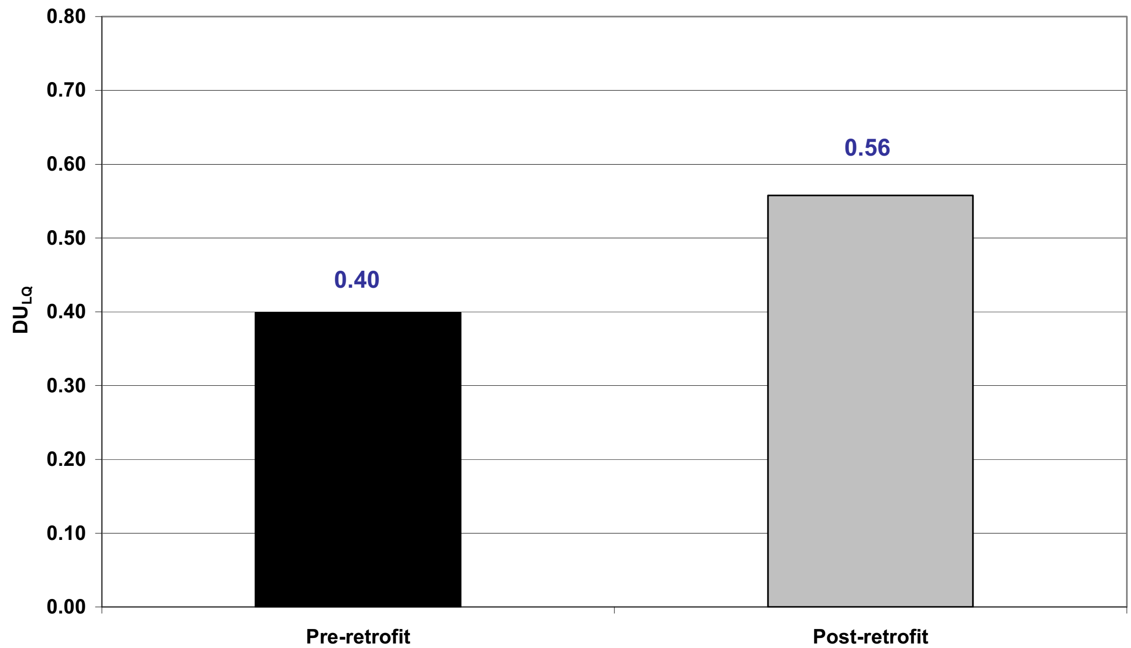
For all the technologies examined to date, the change in distribution uniformity was 0.16 for the 185 stations that were retrofitted and this change is statistically significant (Figure 1). On average the pre-retrofit DU_{LQ} encountered was 0.40 and the post-retrofit was 0.56. On a relative percent difference basis the average improvement for all sites observed was 40%. It should be noted that as per *Data Analyses and Comparisons*, the selection is unbalanced relative to the groupings.

FIGURE 1: Overall DU_{LQ} Comparison
N = 185, p < .000 (Statisically Significant)



In examining the range of the results, one pattern that emerges is that the percentage change in post-retrofit DU_{LQ} following retrofits seemingly decreases with increasing initial DU_{LQ} (Figure 2). This is especially apparent when comparing the Relative Percent Difference (RPD) in post-retrofit DU_{LQ} (R^2 = 0.701) to starting uniformity (Figure 3).

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FIGURE 2: Pre-retrofit DU_{LQ} vs. Post-retrofit DU_{LQ} Improvement Differences

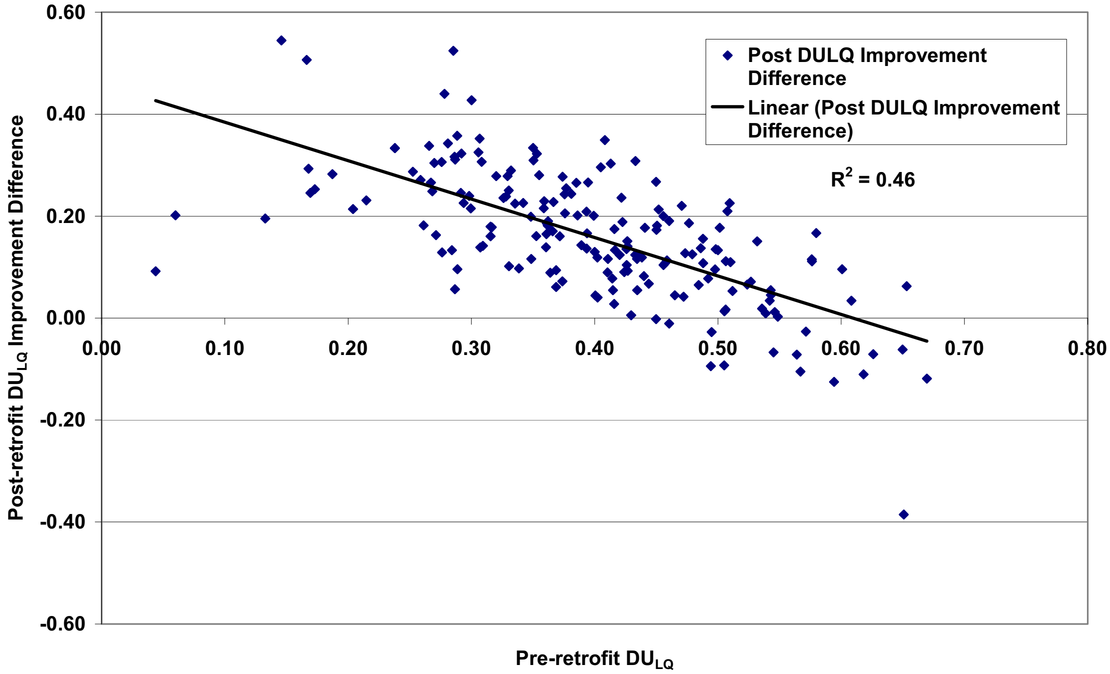
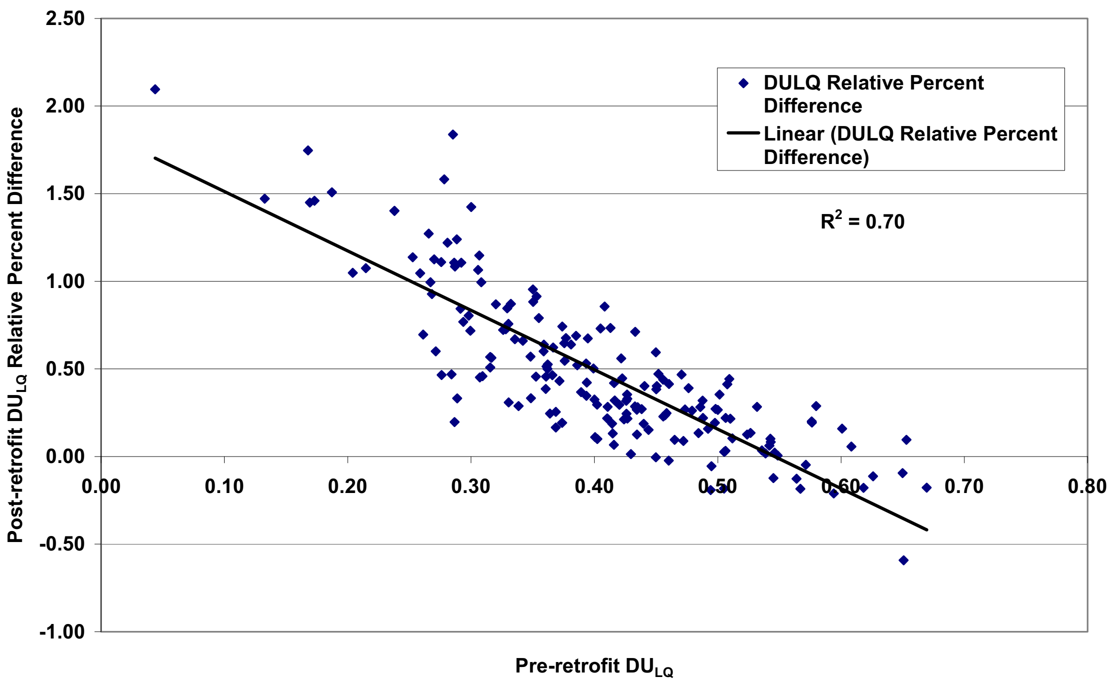


FIGURE 3: Pre-retrofit DU_{LQ} vs. Post-retrofit DU_{LQ} Relative Percent Difference



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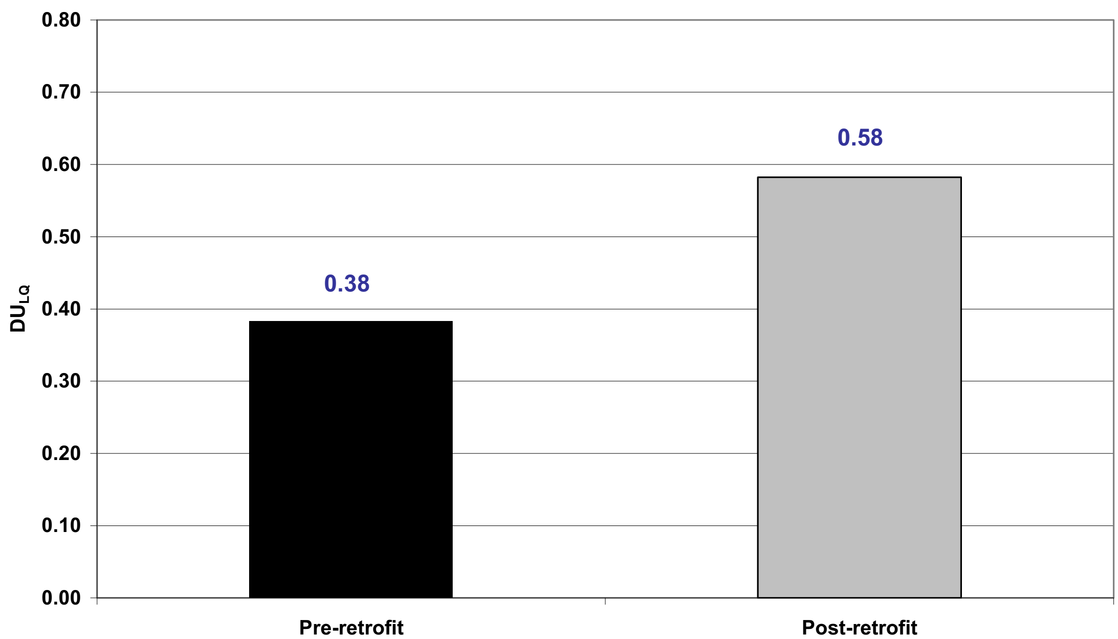
By Treatment Group Results

For all groups, there were no significant differences in pre-installation DU_{LQ} values. In addition to providing reasonable assurance of sufficient sample sizes for the groups, this finding assured that as common as baseline as possible was being used for all *by treatment group* comparisons.

For the Hunter MP Rotators Group (Figure 4), the pre-retrofit average DU_{LQ} encountered was 0.38. Post-retrofit, the average DU_{LQ} was 0.58. The average statistically significant increase in absolute DU_{LQ} was thus 0.20.

FIGURE 4: Hunter MP Rotator DU_{LQ} Comparison
N = 57, p < .000 (Statisically Significant)



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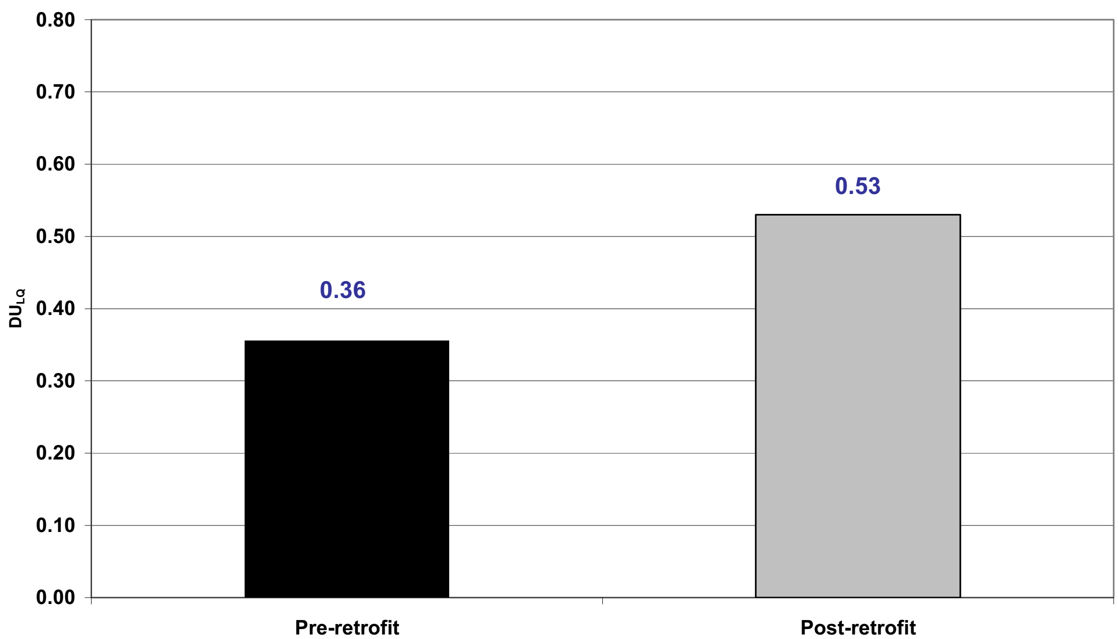
For the Hunter MP Rotators with Little Valves Group (Figure 5), the average pre-retrofit DU_{LQ} encountered was 0.36. Post-retrofit, the average DU_{LQ} was 0.53. The average statistically significant increase in absolute DU_{LQ} was thus 0.17.

FIGURE 5: Hunter MP Rotator with Little Valves DU_{LQ} Comparison
N = 26, p < .000



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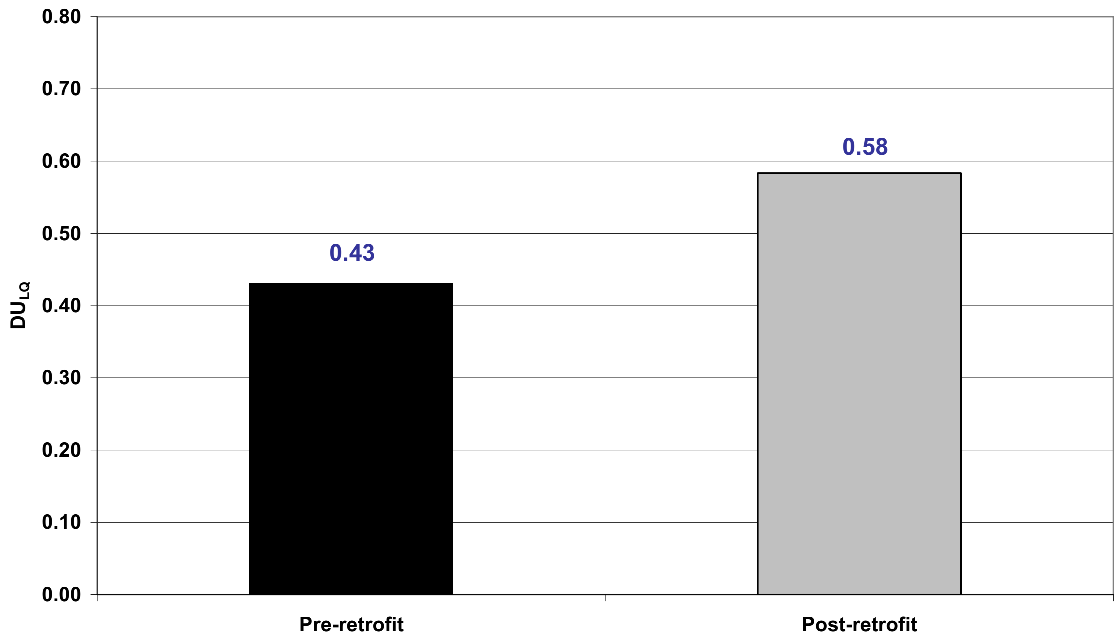
For the Rain Bird Rotary Nozzles Group (Figure 6), the average pre-retrofit DU_{LQ} encountered was 0.43. Post-retrofit, the average DU_{LQ} was 0.58. The average statistically significant increase in absolute DU_{LQ} was thus 0.15.

FIGURE 6: Rain Bird Rotary Nozzles DU_{LQ} Comparison
N = 40, p < .000 (Statisically Significant)



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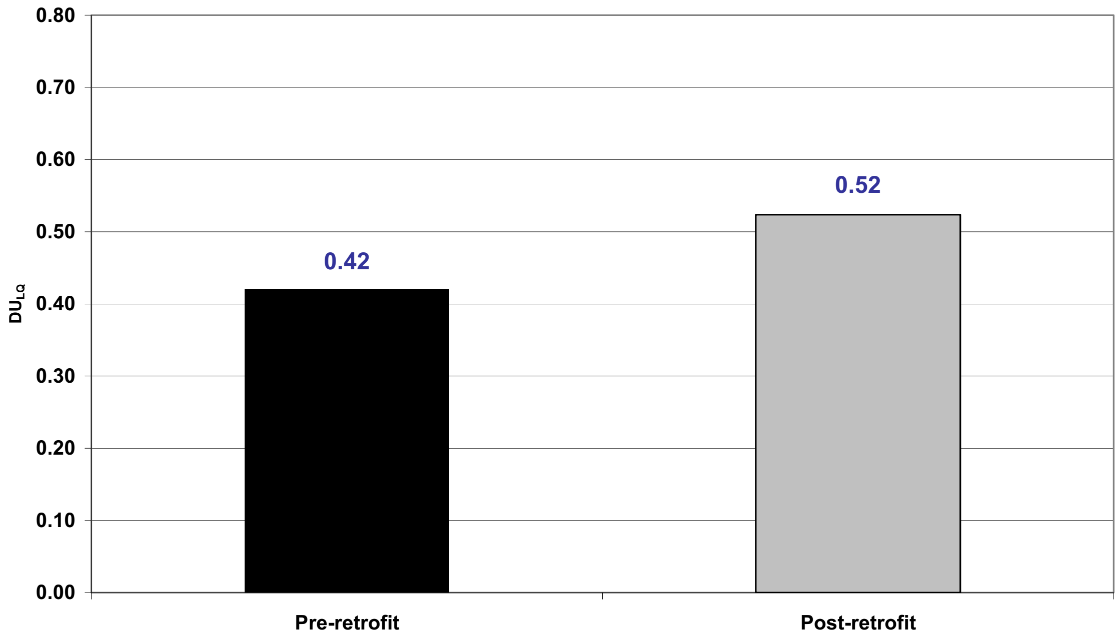
For the Rain Bird Rotary Nozzles with Little Valves Group (Figure 7), the average pre-retrofit DU_{LQ} encountered was 0.42. Post-retrofit, the average DU_{LQ} was 0.52. The average statistically significant increase in absolute DU_{LQ} was thus 0.10.

FIGURE 7: Rain Bird Rotary Nozzles with Little Valves DU_{LQ} Comparison
N = 25, p < .001 (Statisically Significant)



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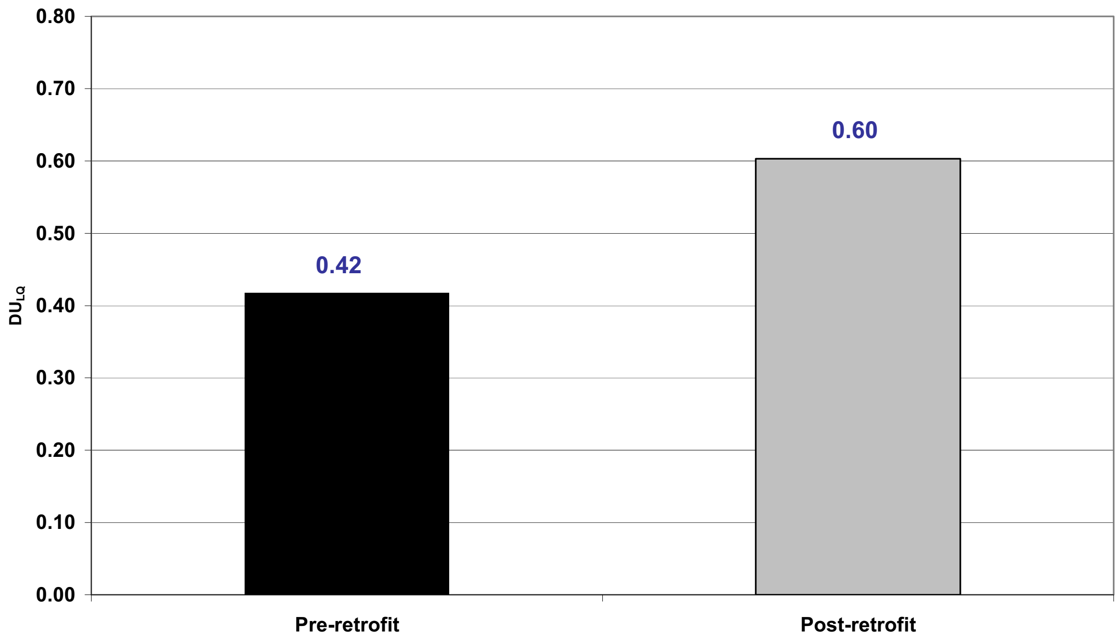
For the Toro Precision Series Group (Figure 8), the average pre-retrofit DU_{LQ} encountered was 0.42. Post-retrofit, the average DU_{LQ} was 0.60. The average statistically significant increase in absolute DU_{LQ} was thus 0.18.

FIGURE 8: Toro Precision DU_{LQ} Comparison
N = 17, p = .000



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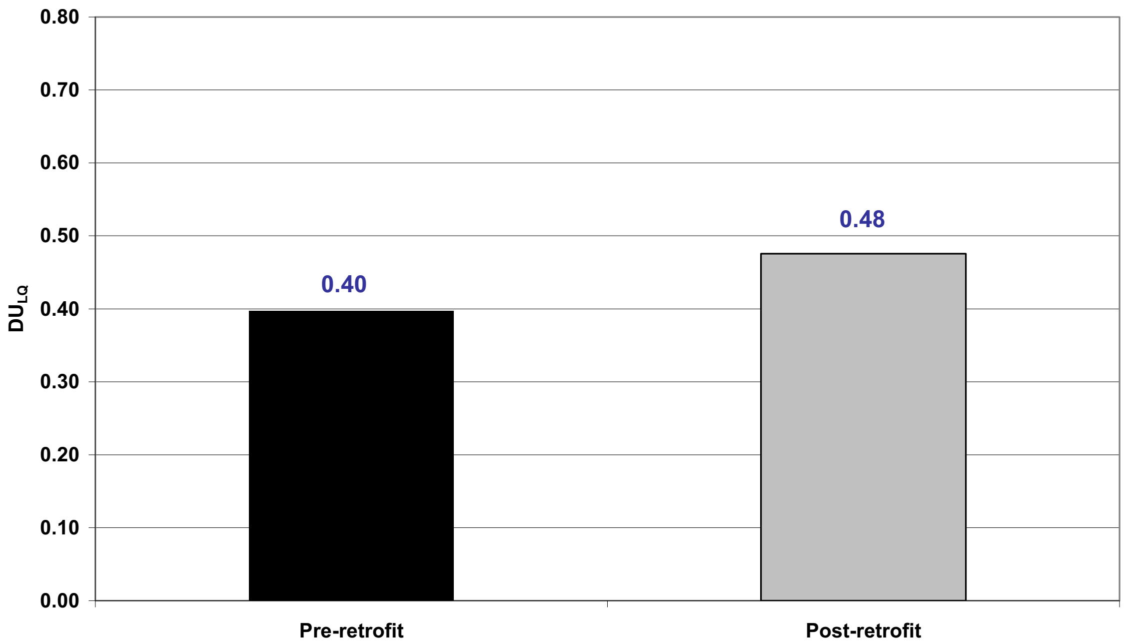
For the Little Valves with Existing Components Group (Figure 9), the average pre-retrofit DU_{LQ} encountered was 0.40. Post-retrofit, the average DU_{LQ} was 0.48. The average statistically significant increase in absolute DU_{LQ} was thus 0.08.

FIGURE 9: Little Valves DU_{LQ} Comparison
N = 20, p < .009 (Statisically Significant)



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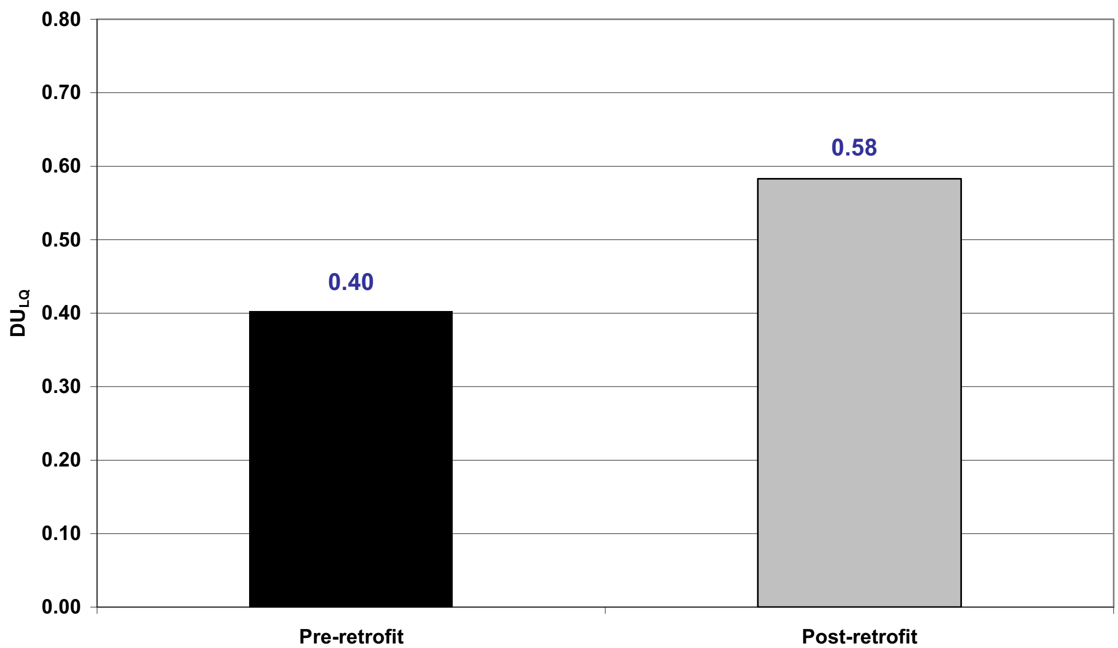
For the All Multi-Stream Rotational Spray Heads Group (Figure 10), the average pre-retrofit DU_{LQ} encountered was 0.40. Post-retrofit, the average DU_{LQ} was 0.58. The average statistically significant increase in absolute DU_{LQ} was thus of 0.18.

FIGURE 10: All Multi-stream Rotational Spray Heads DU_{LQ} Comparison
N = 97, p < .000 (Statisically Significant)



Discussion and Conclusions

Probably one of the largest, most comprehensive studies of DU_{LQ} was done by Mecham (2004). In this study, fixed sprays in the single-family residential sector averaged about 0.52. Focusing more on the Southwest, Aurasteh (1984) found that in a study in Utah, residential systems could average as low as the sub-0.40 range. In another relatively large study, Pitts and others (1996) determined single-family residential systems in a Northern California city averaged a DU_{LQ} of 0.46. Baum et. al. (2005) found in a study in Florida that fixed sprays had an average DU_{LQ} of 0.41.

In the context of the work here done to date the average pre-retrofit DU_{LQ} of 0.40, while relatively low, is certainly within the range of values seen for residential systems. The focus of this manuscript is though on the change that might be accomplished by relatively easy retrofits to fixed pop-up sprays using available technologies. As mentioned the average improvement in DU_{LQ} was 0.16 or 40%

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on a relative percent change basis, taking DU_{LQ} to 0.56, but this is an oversimplification of the dynamics of improvements in uniformity.

For the entire group of properties, as illustrated in Figures 2 and 3 the extent to which DU_{LQ} can practically be improved may well be associated with the initial DU_{LQ} such that the lower the DU_{LQ} pre-retrofit, the more of an improvement the technology may be expected to make. There are of course numerous examples of so called "diminishing returns" in the natural sciences and economic fields. In this case, the results suggest the average DU_{LQ} that can be realized by simple retrofits such as these may not exceed the 50-60% range mainly because this is the point where the diminishing returns nature of the improvements results in RPD essentially reaching zero. Based on the observations, realizing *average* DU_{LQ} values of much more than 0.60 in this area seems unlikely for pop-up sprays in retrofit situations, though of course in some fortuitous *individual* cases such gains can be achieved.

In all of the comparisons above, the improvement in average DU_{LQ} values was significant. For the Multi-Stream Rotational Spray Heads (MSRSHs), whether alone or in combination with the replacement in-stem flow reducers, improvements in DU_{LQ} were realized. Likewise, it should be noted there was no discernable statistical differences in the post-retrofit DU values for the two MSRSH technology using devices. The Hunter MP Rotator and Rain Bird each significantly improved DU to 0.58 and there was no statistical difference between the respective outcomes for the products. For the entire class of MSRSHs, change in DU_{LQ} was 0.18.

The DU improvement realized in this research was unequivocally significant and substantive for MSRSHs. The improvement however did not match with what was predicted in a recent field study (Solomon et. al., 2006). In that study, the predicted average improvement in DU_{LQ} was 0.26. Interestingly though the results are in line with the Farrens data subset that Solomon covered briefly, but did not use in final computations. That subset suggested the improvement in DU_{LQ} was 0.17 which is obviously very close to the 0.18 observed here.

Soloman largely disregarded the Farrens data because it involved in some cases repositioning and elimination of heads (among other issues), explaining that this made the results non-transferable. However, elimination of heads from the authors' observations is often very reasonable given the MSRSHs tend to throw farther than the original installed product (despite the issue, MSRSHs are still the only practical rotors for the range of spacing seen in most single-family residences here). Furthermore, elimination of heads may even be desirable from a water conservation perspective because capping off heads reduces station flow rates. Higher flow rates are associated with greater consumption in the residential sector (Sovocool and Morgan, 2005). Whether or not capping off of

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heads may have lowered DU_{LQ} in this study in some circumstances, as well as whether a trade-off "cost" in DU versus a benefit in station flow rate reduction is worthwhile, is a topic for further research.

The addition of the Little Valve product to MSRSHs did not result in higher DU_{LQ} values, nor were these statistically lower due to the addition of the device. In practical terms the Little Valve did make installations sometimes more feasible where spacing was closer than the design ranges for the MSRSH products. The Little Valve used alone with whatever existing sprays were encountered was able to raise DU_{LQ} to 0.48, a significant improvement as well. In addition to making installations more practically achievable, it was thought that the addition of the Little Valve could further add to the improvement in DU_{LQ} that was anticipated from the installation of the MSRSHs, but since MSRSHs basically improve DU_{LQ} to the 0.50 to 0.60 range anyway and since this may seemingly be a critical threshold per the above discussion, the concept of "stacking" spray head uniformity improvements in retrofits does not seemingly pan out. The sum of the whole is no greater than the improvement from the part with the greatest DU_{LQ} improvement capability.

The Toro Precision Series product also achieved statistically significant post-retrofit savings with the average post DU_{LQ} reaching 0.60. Although the sample size is small relative to the two MSRSH products (Toro joined the study later than the other groups and delivered limited quantities of product), the initial finding is that the oscillating spray technology is capable of matching the improvements in DU_{LQ} seen for the MSRSHs. An inter-group statistical test of the post-retrofit DU_{LQ} results suggests the improvement from the Precision Series Nozzle is not significantly different from that for either of the MSRSHs, and the improvement in DU_{LQ} of 0.18, again suggests improvements associated with using this product are right on par with MSRSHs.

While the technologies presented here successfully achieved uniformity improvements based on the completed retrofit installations, the question of what practical water savings is obtained in field conditions is still unknown for the sample as of this writing. Solomon et. al. (2006) determined the range of *potential* savings may be between 22% and 40% depending on what runtime multiplier (RTM) is used though this was based on a larger absolute improvement in DU_{LQ}. In that manuscript the authors were appropriately careful to use the term *potential* savings, because in part they no doubt recognize that the behavioral aspect of the irrigator is paramount in mediating the relative success of this, and indeed most other, water conservation projects involving irrigation.

What may be unique about SNWA's study, other than the relatively large field sample, is that it aims in its final form to determine the actual water savings obtained with these systems when homeowner behavioral patterns are included

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as a dynamic. Homeowners in this study were educated about the devices immediately post-installation (given a custom schedule with RTMs based on their unique system). After this initial education though, the owner will be essentially on-their-own and could stray, thereby impacting savings. In this regards, the study is designed specifically to mimic what might actually occur as utilities incentivize this technology. Whether “straying” would be positive or negative is unknown considering that a failure to follow SNWA’s recommended increased run times could actually save more water, though this might be to the detriment of the homeowner’s turf quality.

At this time, SNWA anticipates completing the installations in early 2010. At that point the participants will enter a minimum one year monitoring phase to collect data on how they actually use the technologies. At the end of this study, SNWA research staff hope to be able to discover how much these technologies practically do save in Southern Nevada.

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