# GETTING A GRIP ON PRESSURE

*James W. Dettmer, P.E., Malcolm Pirnie, Inc., Tucson, Arizona*
*Karen K. Dotson, AICP, Tucson Water, Tucson, Arizona*
*Todd J. Schram, P.E., Malcolm Pirnie, Inc., Tucson, Arizona*

## Background

The City of Tucson, Arizona is a desert community in the southwest United States that receives an annual rainfall of less than 12 inches per year. The city's water utility (Tucson Water) currently serves a population of over 650,000 people. Historically, Tucson Water has relied heavily on groundwater resources to serve its customers, which has resulted in significant declines of the groundwater table.

In 1984, to help relieve the overdraft of groundwater, Tucson Water constructed a reclaimed water production, storage, and distribution system, which was intended to serve irrigation water to golf courses within and near the City's service area. A subsequent redirection in the customer base focus opened up the system to parks, schools, residences, and other types of customers. In 2001, the system delivered approximately 12,000 acre-feet of reclaimed water annually to about 560 customers.

Because the system was originally designed to serve only golf courses, which usually maintain large, on-site storage facilities from which they pump water to their irrigation systems, the only consideration to delivery pressure at the customers' use sites was that it be sufficient to deliver water at the needed rate to keep pace with daily irrigation needs. As a result, boosting facilities at the production facility must lift water nearly 400 feet, which corresponds to the elevation difference between the first golf course served by the system in 1984 and the production facilities.

Parks, schools, residences, and other smaller customer types generally rely on distribution system pressure to power their irrigation systems. Because of the high lift characteristics of the reclaimed water system described previously, system pressure can vary from as low as 40 pounds per square inch (psi) to as high as 190 psi depending on the proximity of the use site to the booster facilities. These extreme pressures are incompatible with normal operation of most spray irrigation systems, and Tucson Water initiated a study as an update to their *Reclaimed Water System Master Plan* (1999) to identify a target range of operating pressures that is compatible with spray irrigation systems and to develop and evaluate alternatives for consistently providing system delivery pressures within that operating range.

## Planned System Growth

In addition to the 560 customers described previously, Tucson Water is planning to add an additional 64 customers with a cumulative demand of over 6,000 acre-feet annually bringing total annual deliveries to approximately 18,000 acre-feet per year. Over 200 of those customers, representing an annual demand of approximately 6,100 acre-feet, were identified as having sites that use spray irrigation systems that rely on the reclaimed water distribution system to provide the pressure needed to power their irrigation system.

# Pressure Study for Spray Irrigation Systems

A pressure study was conducted to identify the pressure required to power irrigation systems commonly used by existing customers of the Tucson Water reclaimed water system. The pressure study was conducted in two-phases:

The first phase included surveying local irrigation contractors, designers, and suppliers to determine common types of equipment used, desirable ranges of operating pressure, and identification of other system components needed and their associated pressure drops.

The second phase involved a limited field survey of irrigation equipment used by two of Tucson Water's large reclaimed water customers: the City of Tucson Parks and Recreation Department and the Tucson Unified School District (TUSD). Each of these customers maintains several use sites and plans to convert additional sites to reclaimed water use from their current potable sources.

***Survey of Contractors, Designers, and Suppliers***

The survey of contractors, designers, and suppliers identified three common irrigation systems commonly used for large turf facilities and landscaping: 1) rotor sprinklers, 2) spray head sprinklers, and 3) drip irrigation. Rotor sprinkler irrigation was consistently identified as the main method of irrigation for large turf facilities and also requires the highest operating pressures.

***Field Survey of Existing Sites***

The field survey included two school and four park sites. It was conducted to identify sprinkler manufacturer and type typically used by these two major customers. Table 1 presents a summary of the sprinkler head types used by these customers.

**Table 1.** Site Survey of Existing and Potential Reclaimed Water Users

| | Irrigation System Types | | |
|---|---|---|---|
| **Site Name** | **Rotor** | **Spray Heads** | **Manufacturer / Model** |
| Estevan Park | X | | Nelson / 7005 |
| De Anza Park | X | | Nelson / 6005 |
| Catalina Park | X | | Nelson / 6005 |
| Carillo Intermediate School | X | X | Rainbird / 1800 & Champion / Fairway; |
| Safford Magnet Middle School | X | | Nelson / 7500 |
| Military Plaza Park | | X | Buckner Mfg Co. Fresno, CA |

***Sprinkler Performance Survey***

Manufacturers of the types of irrigation heads found on the site survey were contacted for technical data. Based on the information that was acquired, a range of operating pressures, flowrates, and throw distances were tabulated for individual models that were found in the field survey and for similar sprinkler heads available from other manufacturers.

The survey also revealed that there are other components in reclaimed water systems between the connection to the distribution system and the sprinkler heads. The pressure drops across these components must be considered when identifying system pressures that are consistent with the operation of the sprinkler heads. The typical pressure drop for a reclaimed water connection was estimated based on the main components for the irrigation system from water meter to irrigation system header. The estimated system pressure losses included the sum of the pressure drops form a water meter, a filter, and miscellaneous losses, which would include considerations for pipe friction losses, minor losses through valves, and other minor losses. Figure 1 presents a schematic illustrating the assumed pressure losses at each component of the irrigation system beginning at the meter. Based on an assumed meter size of 2”, which is compatible with the size meter used by most turf irrigation sites connected to the Tucson Water reclaimed water system, a total pressure drop for a typical connection was estimated at 17 psi.

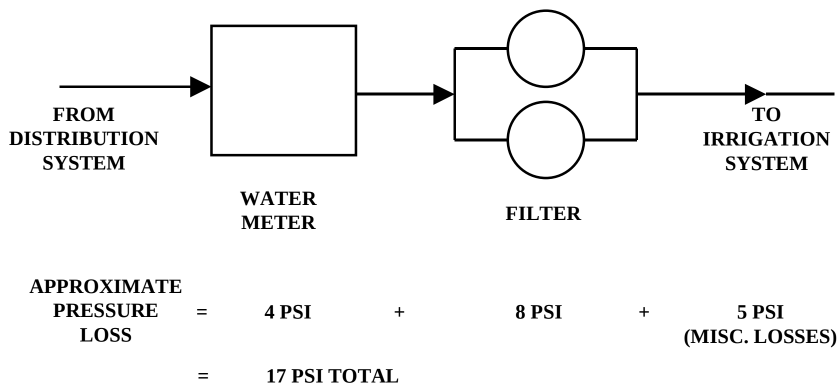


**Figure 1.** Pressure Losses for Irrigation System Components

Table 2 presents the findings of the sprinkler survey for rotor and spray head sprinklers. For each sprinkler model, a pressure range required at the meter was calculated that accounts for the estimated 17-psi pressure drop through the irrigation system components. These values reflect the range of pressures that could be established as a pressure goal for reclaimed water distribution systems.

**Table 2.** Operation Data for Rotor and Spray Head Sprinklers

| Company | Model | Pressure Range (psi) | Flowrate Range (gpm) | Radius (feet) | Pressure Range at Meter (psi) |
|---|---|---|---|---|---|
| **Rotor Sprinklers** | | | | | |
| Nelson | 6005 | 25 – 65 | 0.9 - 7.5 | 26 – 42 | 42 – 82 |
| Nelson | 7005 | 40 – 90 | 6.7 - 18.4 | 46 – 64 | 57 – 107 |
| Nelson | 7500 | 40 – 90 | 9.4 - 28 | 40 – 74 | 57 – 107 |
| Rainbird | Eagle 500 | 40 – 100 | 6.0 - 13 | 33 – 49 | 57 – 117 |
| Rainbird | Eagle 700 | 60 – 100 | 17 - 44 | 55 – 80 | 77 – 117 |
| Rainbird | Eagle 900E | 60 – 100 | 21 - 57 | 63 – 91 | 77 – 117 |
| Hunter | G90 | 60 – 100 | 32 - 69 | 74 – 96 | 77 – 117 |
| Hunter | G870 | 50 – 100 | 13 - 34 | 53 – 75 | 67 – 117 |
| Hunter | G60-ES | 40 – 60 | 6.5 - 21 | 51 – 66 | 57 – 77 |
| Toro | 644 | 40 – 90 | 6 - 25 | 47 – 67 | 57 – 107 |
| **Spray Head Sprinklers** | | | | | |
| Rainbird | 1800 | 15 – 70 | - | 1.5 – 10 | 32 – 87 |
| Champion | 18 (Fairway) | 20 – 90 | - | - | 37 – 107 |
| Buckner | BPH M | 15 – 50 | - | 6 - 15 | 32 – 67 |

## Establishing Pressure Ranges

There is a wide variation in the manufacturers' specified operating pressures for the sprinklers evaluated. The range of operating pressures varied between 15 and 100 psi. In general, the spray head sprinklers are able to operate at lower pressures (minimum operating pressures between 15 psi and 20 psi and maximum pressures between 50 psi and 90 psi) than the rotor sprinklers (minimum operating pressures between 25 psi and 60 psi and maximum pressures between 65 psi and 100 psi). The throw radius for the spray head sprinklers, however, is much lower (1.5 feet to 15 feet) than for the rotor head sprinklers (26 feet to 96 feet).

Of the ten rotor heads evaluated six are able to operate at a minimum pressure of 40 psi or less. The throw radius of those sprinklers varies from 26 feet to 51 feet at their respective minimum operating pressures. If a 17-psi pressure loss from the meter to the sprinkler heads is assumed (see Figure 1) a pressure of 57 psi is required from the reclaimed water system to the meter to meet the minimum pressure requirements of those sprinklers without the use of a booster pump at the site.

Nine of the ten rotor sprinkler heads evaluated can operate at pressures of 90 psi or higher. Again, assuming a 17-psi pressure drop from the meter to the sprinkler head, a maximum pressure in the reclaimed system of 107 psi would allow the sprinklers to operate without on-site pressure reduction.

If reclaimed water system pressure can be maintained between 60 psi and 100 psi at the use site meter, the assumed range of pressure available at the sprinkler head would be between 43 psi and 83 psi, which falls within the acceptable operating range of most of the gear-driven rotor heads identified. Maintaining this pressure range within the reclaimed water distribution system was, therefore, used as the basis for system improvement alternatives. It should be noted that at lower operating pressures, individual sprinkler heads will exhibit a shorter throw radius than the same heads at higher pressures, which could significantly impact the number of sprinkler heads required. In low-pressure applications, the cost of additional sprinkler heads will need to be evaluated against the cost of a suitably sized booster pump.

## Existing Distribution System Pressure

The distribution system was modeled under existing conditions to identify the pressure distribution within the system. The modeling indicated that there was a total of 32 existing and 21 future sites in the Tucson Water reclaimed water system, with a combined total annual demand of approximately 1,600 acre-feet that are located in areas where the pressure is above 100 psi. Eighteen existing and five future sites, with a combined total demand of approximately 1,400 acre-feet, were found to be located in areas where the system pressure is below 60 psi

## Alternatives for Meeting Pressure Range

Three alternatives were developed for providing reclaimed water at the desired pressure range throughout the distribution system. The alternatives are based on developing system-wide modifications, local modifications, and on-site modifications to provide system pressures that fall within the desired range of 60 psi to 100 psi. Each of those alternatives is described in the following sections.

***Alternative No. 1 – Establish Pressure Zones***

Alternative No. 1 consisted of providing booster pump stations at selected sites within the distribution system. Under this alternative, the Boosters located at the production facility would boost to approximately 100 psi, which would provide sufficient pressure for the areas currently identified to be above 100 psi. To compensate for the reduced pressure entering the system, a booster station would be located at the interface of the current high-pressure area and the area where system pressure currently falls between 60 psi and 100 psi. These booster stations would also discharge at approximately 100 psi.

***Alternative No. 2 – Establish Local Distribution Networks***

Alternative No. 2 included developing smaller, local distribution networks to serve groups of use sites that lie outside of the zones of adequate pressure in the existing and planned distribution system. Under this alternative, groups of proximate sites would be identified and a new pipeline, installed parallel to the existing distribution system, would be installed. A pump or PRV would be located at the turnout from the main distribution system to provide appropriate pressure to the smaller distribution network.

***Alternative No. 3 – Provide On-Site Boosters or Pressure Reducing Valves***

Under Alternative No. 3, individual on-site boosters would be provided at sites where the distribution system pressure is below 60 psi, and on-site PRVs would be provided where system pressure is above 100 psi. This arrangement would provide the most flexibility and is what is currently being done at most sites.

## Evaluation of Alternatives

Capital needs to incorporate each of three alternatives were identified and are summarized below:

Alternative No. 1 would require installing twelve new booster stations with flow capacities varying between 1,400 and 17,000 gpm (average 6,400 gpm per station). The estimated capital costs associated with this alternative totaled $35 million.

Alternative No. 2 would require installing eleven new boosters stations with capacities varying between 80 and 2,500 gpm (average 690 gpm per station). In addition, ten loops were identified that would need pressure reducing valve stations with capacities varying between 140 and 1,400 gpm (630 gpm average per station). The estimated capital cost associated with this alternative was $ 7.3 million.

Alternative No. 3 would require installing 46 individual use-site booster pumps and 81 individual use site pressure reducing valves. The capacities of the boosters and valves would be matched to the maximum irrigation needs of each site. The estimated capital cost associated with this alternative was $1.3 million.

Planning-level capital, annualized, capital, and annual operation and maintenance (O&M) for each of the three alternatives are presented in Table 3.

**Table 3.** Capital and O&M costs of Alternatives

| Alternative | Description | Capital Costs ($ Million) | Annualized ($ Thousand) | | Total Annualized Cost ($ Million) |
|---|---|---|---|---|---|
| | | | Capital Costs | O&M | |
| 1 | Establish Pressure Zones | 35.0 | 2,900 | 650 | 3,550 |
| 2 | Establish Local Distribution Networks | 7.3 | 600 | 40 | 640 |
| 3 | Provide On-Site Boosters or Pressure Reducing Valves | 1.3 | 100 | 20 | 120 |

## Conclusions

1. There is a wide variety of spray and rotor heads available that can operate over a wide range of pressures. Many can satisfactorily operate at pressures as low as 40 psi and as high as 100 psi. Pressure losses through the site equipment, including the water meter, irrigation system filter, and irrigation system distribution piping is generally less than 20 psi. If pressure in the system is maintained between 60 psi and 100 psi, commonly available irrigation sprinklers can be obtained that will operate satisfactorily.

2. Alternatives to establish delivery pressures between 60 and 100 psi were developed to resolve pressure problems at sites with irrigation systems connected directly to the reclaimed water system. Establishing pressure zones within the reclaimed water distribution system to regulate

system-wide pressures is the most costly option of the three investigated, but provides a consistent service, a long-term solution, and operational and planning flexibility. The addition of booster / PRV stations at proposed zone boundaries would also make operational duties more intensive. The least cost alternative for providing the needed pressure at the use site is provision of an individual pump or PRV for each site, where needed.

3. It is extremely important to understand the needs of the target customer base when planning and designing a new reclaimed water distribution system. Proper planning early on can make it easier for customers to make use of a reclaimed water system and can help to reduce operating complexities and costs associated with retrofits.