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Sustainable Landscape Design Strategies for Maximizing Rainwater Use and Increasing Irrigation Efficiency

Landscape is generally considered a decorative commodity in the architectural design field, water industry, and public mind. The American landscape ideal is a water- and maintenance-intensive landscape dominated by lush, green turf that never gets brown, never gets weedy, and in most cases has no relevance to its region, especially in the Southwest. Rooted in the English landscape model of a gentleman's country-estate lawn, the ideal has become a landscape industry convention. Pushing this ideal relentlessly toward prevalence are outmoded design and management mindsets and techniques that create landscapes in conflict with their environments. In the arid Southwest, the consequences of this conflict are nowhere more apparent than in irrigation water use.

The need for intensive irrigation arises when landscapes cannot live and thrive solely through the natural conditions of their environments. This often happens when cultural convention comes into conflict with ecological reality. Instead of self-sufficient, regionally relevant landscapes, we create weak, exotic ornaments that require constant attention. Their irrigation regimes are the equivalent of landscape life support. At the first sign of yellowing grass or brown leaves, we simply increase irrigation. This "just add water" remedy is another convention the landscape maintenance industry, water professionals, and public entities are examining with increasing scrutiny and often rejecting.

Technology alone cannot solve the conflict between water conservation and irrigation-greedy landscapes, though it's where we often go for solutions. Developments in irrigation technology are imperative for addressing water use issues and sometimes provide excellent solutions. However, design and management professionals are increasingly discovering that an integrated, holistic mindset – an approach commonly placed under the banner of "sustainable design" -- can be as or more effective than the best technological tools. When technology is integrated with design and planning techniques, the irrigation efficiency and performance of landscapes move toward a new ideal, one that is regionally relevant, self-sufficient, and regenerative.

Landscaping in the arid zones of the Southwest provides an excellent opportunity for demonstrating the efficacy of sustainable design and management strategies in reducing irrigation demands. With natural rainfall as a pivotal element, my design approach exploits regional environmental conditions instead of disregarding or fighting them, resulting in highly efficient landscapes that generate habitat. Dubbed "total hydrology planning," the approach is an integrated, holistic strategy that includes key techniques often used in sustainable design, though many are also part of conventional landscape planning and management. Like technology, standard practices can play an important role in the irrigation-efficiency solution when integrated in a total hydrology approach. This integrative process dovetails seamlessly with green building, significantly impacting US Green Building Council LEED scores in the credit sections of Sustainable Sites, Water Efficiency, and Energy and Atmosphere, as well as Operations and Maintenance. This paper will discuss how total hydrology planning's essential design techniques – especially maximization of rainwater -- can contribute to landscape irrigation efficiency, and even irrigation elimination.

Strategies

Planning landscapes to capitalize on available rainwater improves irrigation efficiency by manipulating the three components of water catchment systems, water supply, water demand, and how water is delivered to plants. Maximizing rainwater use does more than reduce demand on municipal and other water sources. It improves plant health, lowers maintenance requirements, builds healthy soils, generates habitat, and creates landscapes that are highly relevant to their specific environments.

Total hydrology planning encompasses many strategies that collect rainfall passively, distributing water to plants and retaining moisture through gravity, shade, and topography. These are integrated with active catchment systems, more complex systems that use technology to harvest and store rain, and irrigation technology to achieve efficient goals.

1. Start with a wide, all-encompassing perspective.

Observation with a view toward the big picture is paramount, not just during the data collection phase of design but throughout the process and its evaluation. It starts with a careful examination of overarching factors impacting the site, including those located beyond site boundaries. When planning more than one site, as in the case of a conservation subdivision, boundaries blur even further. Many of the results of this observation step will naturally direct decisions for passive rainwater collection to boost supply and planting selections to reduce demand.

For example, climate data analysis should include average temperature highs and lows, prevailing winds, ambient moisture season to season, and monthly rainfall. Collect site data including property dimensions, municipal location, orientation of buildings, and solar information. Pay attention to adjacent properties and their uses, the topography of the site, and any off-site conditions that can contribute to the water shed. Measure high points, low points, direction of slopes, and unusual circumstances, such as an area that appears to pond or lacks vegetation. Note anything that subtracts or adds to the site's total moisture, such as water draining from a street or parking lot onto the property that can be used to increase to the supply side of the water budget. Inversely, note water that runs onto adjacent property that should be used on-site before it is allowed to drain off. Map out hardscape including parking, walks, and plazas, as well as roof plains of all buildings. Take note of where the water drains from roofs, both drip edge and downspouts, as these will be useful in locating plantings or determining if drainage locations should be adjusted. Learn about vegetation types growing on the site and in the neighborhood. Conduct a visual soil test from multiple locations around the site with a shovel or soil probe, making note of general soil consistency and type, such as clay, sand, silt, and rock. Sometimes, geotech borings from previous construction are available. Take samples from a variety of locations and test for PH and N.P.K. This information will become very valuable.

Observation and analysis of existing conditions were pivotal to the success of landscape at the Northern Arizona University Applied Research and Development Facility, a LEED Platinum project located in the high, dry climate of Flagstaff, Arizona. The site plan was organized around a municipal on-campus basin, a potential constraint we turned into an asset to help meet the project goal of reducing water consumption by 60 percent. We used site-excavated limestone to direct run-off, recycled plant biomass as mulch to build soil, and re-designed the basin as a wetland planted with plant species appropriate to climate and elevation. Combined with active catchment from building and hardscape, the design effectively manages water and fits in with surrounding environment.

2. Calculate supply and demand for a total moisture budget.

Based on site data collected, determine the total moisture budget based on supply and demand. When calculating supply, include run-off from all surfaces, including off-site ones. Create a plan view drawing that delineates every sub-water shed, then note potential run-off figures. Start by multiplying total square footage by .62 gal., the standard calculation for approximating run-off from a 1-inch storm. Adjust this figure using run-off coefficients for various surfaces, as listed in Figure 1. Runoff Coefficients of Various Surfaces. Finally, multiply this by volume according to month-to-month precipitation data for the area. This is the site's naturally occurring supply.

After supply is estimated, calculate demand. Start with the highest demand period, the plant establishment phase. Keep in mind that irrigation demand will decrease as plants mature. A one- to two-year establishment period is usually appropriate, depending on plant selection. Calculate the number of emitters required per plant based on water volume and delivery rate. Estimate the number of one-hour irrigation cycles required per week or month during the growing season, adjusting for turf or other plant dormant seasons, if applicable. Multiply number of plants by required irrigation cycles. Then, multiply this by square footage of planting area. This is the site's water demand. For an example of a water budget calculation for a yard in Arizona where average annual precipitation is 13.9 inches, see Figure 2. Water Demand Calculation for a Small to Medium Landscape in Prescott, Arizona.

The site's total moisture budget is estimated by combing supply and demand. Just as in a financial budget, when demand exceeds supply there is a deficit. When supply exceeds demand, there is a surplus. Optimally, the final landscape plan will fit the moisture budget exactly. This doesn't mean restricting a design to existing conditions. Design techniques let us manipulate design elements to increase supply and decrease demand.

3. Manipulate runoff through grading and earthworks.

The design process begins after a total moisture budget has been developed. The primary goal of this phase is to use design and planning to manipulate conditions that affect water supply and demand, freeing the design to meet desired planting requirements. Grading and earthworks help direct, capture, and retain run-off, adding it to the site's supply.

Conventional landscape techniques that can impact water supply include terracing with earth or retaining walls, building earth berms to capture and hold water in plant beds, and installing dry wells and French drains. Total hydrology planning integrates these with sustainable techniques such as on-contour swales, meandering drainage swales, and head-to-toe rock cheek dams. Manipulate run-off to targeted areas through finish grading to maximize soil saturation in plant beds, making for healthier plantings and encouraging mulch and microorganism participating in the soil nutrient cycle. Mitigate stormwater runoff by keeping it on-site or filtering pollutants from water before it leaves. Create moisture zones by manipulating moisture shed from hardscape and building roofs. Incorporating flat-bottom planting infiltration basins into designs not only delivers and retains moisture for plantings, but also creates natural catchalls for leaves and other debris that build soil.

Swales planted with appropriate species enabled us to increase the planting palette of a zero-energy demonstration home in Borrego Springs, California. These experimental, energy-efficient and sustainable production homes are located in an area consistently ranked as one of the hottest in the United States. Surrounded by 600,000-acre Anza-Borrego Desert State Park, the arid site enjoys expansive desert and mountain vistas, but gets just six inches of rain per year. The goal was to create a self-sufficient landscape requiring no supplemental irrigation after plant establishment. This initially gave the project an extremely limited planting selection. We expanded it by concentrating run-off into planted bio-swales, where absorbing tilled-biomass makes rainwater available to a greater number and diversity of species. Attractive rain chains on the structures celebrate water, while salvaged rock and boulders shelter plantings and merge the new landscape with its desert environment. Native, drought-resistant plants salvaged from construction require no potable water irrigation. When rain is scarce, stored rainwater is applied.

4. Select plants for optimum performance.

Just as building swales and directing run-off increases the supply side of the water budget, selecting native and well-adapted plants suitable to the environment reduces demand. Plant selection provides numerous opportunities to improve a landscape's ability to take advantage of irrigation from naturally occurring or manipulated run-off sources. Typical design adjustments made here include swapping, shifting, and eliminating plants to meet optimum irrigation allowable by existing field conditions.

To determine a baseline planting plan, revisit the preliminary plant list and plan, overlaying them with the site's total moisture budget, including supply gained through run-off manipulation. Take into account dry areas created by lack of water concentration as well as wet areas created by concentration. Of course, this includes all water sheds from adjacent landscape topography, sidewalks, patios, house, and other buildings on the site. Choose native and well-adapted plants that are good for habitat and relevant to regional ecology.

Put plants into hydro-zones, created when plants are grouped together based on irrigation requirements. Each drip irrigation circuit is cycled separately so that each plant zone is also a separate drip zone. For example, fruit trees would be one hydro-zone, native shade trees another. Their irrigation requirements and establishment periods vary. Plants in their appropriate hydro-zones get neither over- or under-watered.

A joint public library project between the Town of Prescott Valley and Yavapai College in central Arizona called for an exceptional level of understanding of local indigenous plants and environment. The architect oriented the site plan and building to an extinct volcano that dominates the town's landscape and history. Accordingly, the landscape plan concept, materials, and planting schemes were driven by the hill's geology and plant life. Incorporating aggressive rainwater collection and energy efficiency, the plan used a completely native plant palette supported by earthworks and salvaged native stone. After a two-year establishment period, these native plants will thrive solely on natural precipitation.

5. Create microclimates by manipulating solar variables.

Sun and shade are crucial components for creating on-site microclimates where habitat can thrive. Shade directly affects moisture retention and plant selections. Hot and dry areas are dominated by exposure to full or reflected sun, while shady areas can be created by vegetation and site walls, fences, and buildings. An obvious way to provide shade is through trees, but shrubs, small plants, and boulders play a relative role in shading a site. An easy way to significantly increase shade is to expand a building in a strategic location, such as

- Garage addition on west elevation
- Trees on east and west elevations
- Porches, outdoor rooms, or arbors planted with vines
- Green fences, green walls, and green roofs.

Inversely, take advantage of hot, sunny areas by planting full-sun natives. Cactus, agave, yucca, and acacias are some of the most interesting and sculptural plants on the continent, and they live here in the Southwest. Use them.

In Phoenix, Arizona, shade is a premium commodity much of the year. With 334 days of sunshine and average summer temperatures in the triple digits, designing shade into plans is a must for creating healthy landscapes. Mission Lane is a city redevelopment project comprised of nine, two- and three-story multi-family housing buildings oriented east-to-west and designed for passive solar heating and cooling. The courtyard spaces created between structures were shaded with native shade trees pushed away from south elevations to welcome winter sun. To shade the buildings in summer, we used dense vines on east and west elevations, as well as shade trees placed where space allowed. Shade-tolerant shrubs were planted on shady north elevations and heat-tolerant desert species on sunny southern ones. The result is a diverse, water-efficient landscape encompassing several microclimates including cool, shady and moist and hot, sunny and dry.

6. Build soil.

Soil is where all the elements of total hydrology planning come together. Conventional landscape design and maintenance treats soil merely as a growth medium. Seen as a means to an end, soil is treated as a passive, secondary receptacle for fertilizer and water, something necessary to get turf, trees, and shrubs to grow faster or better.

Actually, soil is by far the most important part of the water budget equation. When treated as a vital participant in healthy landscape, soil is a self-fertilizing system that uses water as efficiently as possible. Soil is composed of fragmented minerals in the form of rock, gravel, sand, silt, and clay. This essential structure of a given soil has bearing on its ability to hold and release moisture, thus support plant life. Landscapes can participate in the soil-building cycle by providing soil with plenty of organic material to break down, rainwater to aid and support microorganisms, and a design that provides time for the process to succeed. Basins designed in grading and earthworks planning collect leaves, duff, and water to be gradually integrated into the soil, where they are gradually broken down into important nutrients.

Soil should be tested for PH as well as the ratio of nitrogen, phosphorous, and potassium content present (NPK). Available ratio of NPK affects plant growth, though it is more important to fruit and vegetable production than traditional landscape plants. Living organisms in soil make all the difference in its moisture and nutrient content. Bacteria and microrrhizas (symbiotic associations between a fungus and the roots of a plant) live in the soil, breaking down organic matter and making nutrients available to plant life. Commercial, petrochemical-based fertilizers, herbicides, and pesticides eliminate these beneficial microbes. Microorganisms do their job much better when fed a good supply of rainwater.

Designs should call for planting beds to be finished with a top coating of organic mulch. Mulch accomplishes many tasks for a landscape. It controls weeds, holds moisture in soils, and insulates them from solar radiation. It feeds soil building as it rots by providing food for microorganisms as well as earthworms and other tunneling, aerating insects. Wood chippings are often readily available but any large, shredded, organic matter will do, as long as it is heavy enough to withstand wind.

7. Augment supply with active water catchment.

The most important component in boosting the supply side of the landscape moisture budget is active water catchment. This includes rainwater collected off of roofs, filtered, stored in below- or above-ground tanks, and re-distributed when needed by pump, gravity, or through an irrigation system. It also includes grey water reclaimed from domestic plumbing, including laundry, bathing, and kitchen water. Both increase control over water supply without requiring potable water sources.

Grey water can be used as irrigation water in some states and municipalities. Already popular as a supplemental irrigation water supply, it is a reliable source that can be put into earth works for plant beds. Grey water comes with some special considerations that require applying it to landscapes with discretion. Generally, the less contact it has with human activity, the better it is for landscapes. It is best not stored but applied immediately to soils that will absorb it quickly. Care should be taken to prevent use of grey water than contains chemicals from items such as bleach or sodium-based detergents.

Active rainwater catchment, or harvesting, systems are far better for landscape irrigation. In addition to providing plants vital nutrients free of chemicals found in municipal water, rainwater drives salts away from plant roots, creates soil-building environments, and eventually filters back to the water table. Rainwater collection systems consist of a water-shedding surface (usually a roof), gutters, downspouts, filtering system, and a catchment and storage device. More complex systems include monitors, pumps, and other equipment to aid in water delivery and integrate with irrigation and grey water systems. The primary difference from passive catchment is that active systems store captured water for re-use at times and volumes under your control.

To maximize active rainwater catchment in landscape design, dovetail it with passive techniques such as those already discussed here and integrate it with other water-delivery systems. Overflow may be directed to swales or planting beds where thirsty plants are placed. Tanks may be used to create shade and windbreaks. Rainwater systems may be tied into irrigation systems already in place.

Conclusion

Approaching landscape design through a total hydrology mindset has benefits that extend far beyond irrigation efficiency. When landscapes no longer require life support, the impacts on maintenance are profound. Healthy, regionally appropriate landscapes are inherently low-maintenance. Weak, decorative exotic plants that demand continuous care are replaced with species that create self-sustaining, regenerative habitat. Plants thrive on the delicious rainwater they love, instead of being overdosed with chlorinated municipal water. Soils regenerate nutrients through retained rainwater and by breaking down leaves and other organic material left alone to decompose. The vicious cycle of fertilization-weed control-fertilization is eliminated. Combined, these effects save time and money, in addition to water.

Looking again at the big picture, stormwater flow is mitigated and run-off that does leave the site is filtered of pollutants that would otherwise end up in wastewater systems, rivers, and other bodies of water. Most important, demand is eased on natural resources such as potable water supply.

Figure 1. Runoff Coefficients of Various Surfaces

Surface Area Use	Runoff Coefficient
Open Space	.39 - .84
Commercial	.89 - .93
Residential, Half Acre	.54 - .85
Parking, Paved Roads, Roofs	.98
Gravel Roads	.76 - .91

U.S. Soil Conservation Service, 1975

Figure 2. Water Demand Calculation for a Small to Medium Landscape in Prescott, Arizona.

1. Calculate emitter per plant.
   1 gal. plant = 1, 1 gallon per hour emitter
   5 gal. plant = 2, 1 gallon per hour emitters
   15 gal. plant = 3, 1 gallon per hour emitters
2. Number of plants x irrigation rate.
   50, 1 gal. Plants = 1, 1 gallon per hour emitter = 50 gal./hr.
   30, 5 gal. Plants = 2, 1 gallon per hour emitters = 150 gal./hr.
   12, 15 gal. Plant = 3, 1 gallon per hour emitters = 180 gal./hr.
   Total Gallons per hour for this landscape = 380 gal.

3. Adjust for establishment period and seasonality.
   Summer (April through October)_
   1 time per week @ 2 hrs.
   760 gallons x 24 weeks = 18,240 gallons

   Winter (November through March)

1 time per month @ 2 hrs.
760 x 6 months = 4,560 gal.
Annual demand = 22,800 gal.

Figure 3.