RAINWATER HARVESTING AS A DEVELOPMENT-WIDE WATER SUPPLY STRATEGY

by David Venhuizen, P.E.

The “normal” approach to providing water supply to a development is to extend water lines from the local water utility and to buy water from that entity. This is, however, a strategy that may be questionable in terms of overall long-term sustainability in Central Texas. If the population growth forecast for this region occurs, and if the per capita water demand on its current supply sources does not significantly decrease, it is expected that this region would have to begin importing water within a couple decades. It is an open question just where this water might come from, as all the river basins in this region are expected to be over-committed.

The rational conclusion is that developments indeed “should” be designed to enhance water use efficiency as much as practical. Rainwater harvesting, and the efficiency practices which it would stimulate, may be an avenue to this end, providing fiscal, societal and environmental benefits. Therefore, a proposed water supply strategy is to investigate a system predicated on direct, building-scale rainwater harvesting to be employed instead of, or in some combination with, a piped supply.

The building-scale rainwater harvesting concept envisions collecting rainwater off building roofs and routing this water to a cistern, perhaps integrated into the structure of each building but certainly “associated” with that building – e.g., a free-standing cistern on the same lot. Each building would therefore incorporate a self-contained water supply system, including all facilities required to filter/treat/disinfect the water so that it can be used to supply all water demands—including potable—within and around that building. Each of these buildings would however be “connected” to a development-wide water system through an organized, assured backup supply scheme.

A building-scale rainwater harvesting strategy is conceptually quite rational. Building-scale rainwater harvesting is one of a limited number of options for a Central Texas development. The others include a well on the development and a small-area distribution system, connecting to an existing water supply system, and importing water from reservoirs in “regional” scale water transmission mains. These are all essentially large-scale rainwater harvesting systems, with reservoirs or aquifers serving as the system’s “cistern”. This highlights that there is nothing “exotic” about rainwater harvesting as a water supply strategy. Since all fresh water derives from rainfall, just about every water supply system in the world is a rainwater harvesting system. They differ only in how long and convoluted the link is between the precipitation and the water usage, so conceptually they differ only in scale. The findings and recommendations in “Rainwater Harvesting Potential and Guidelines for Texas”, a report to the 80th Texas Legislature, indeed make it clear that a rainwater harvesting water supply strategy is anything but a wild idea out of the blue. Rather it is a mainstream-method-waiting-to-happen, given an appropriate context.

The immediately obvious question about rainwater harvesting as a water supply strategy is, “What happens in a drought?” Because there is a practical limit to the cistern volume that can be provided to sequester rainwater on the site, the building-scale rainwater harvesting system would have to incorporate provision of backup supply from those large-scale “cisterns” – reservoirs and aquifers. Given appropriate arrangements for that backup supply, the building-scale rainwater harvesting system can be made as immune to loss of supply during a drought as any other system. The only question is how “practical” and cost efficient those provisions may be in any given context vs. simply connecting to one of those larger-scale water supply systems, a matter that is explored further below.

Lacking explicit information about how far the line from a water utility must be extended to reach the project, and on what improvements – such as line enlargements, storage tanks, and pumping stations – would be needed to provide sufficient supply, on what schedule water could be made available, or what it would cost, one cannot speculate in the general case what would be the direct fiscal implications of relying on rainwater harvesting for any part of the water supply for a project. However, the following factors indicate that it may be profitable to develop this line of attack:

- The short-term cost efficiency may be compelling, and over the long term, the time value of money may also favor a pay-as-you-go strategy. The large-scale infrastructure is an "all-or-none" decision requiring a very large investment well in advance of *any* delivery of service, financing large-scale facilities that would not be fully utilized for many years. All users of this system would be paying the cost of these unused facilities throughout that period.
- Again noting the uncertainty about transport fuel costs, *and* about the real estate market generally, if buildout does not proceed as contemplated, the developer and/or system users would be left to pay back this investment with short revenues, perhaps drastically increasing water rates or taxes dedicated to paying off this debt.
- In contrast, while the initial cost per gallon they incur may be higher, the building-scale rainwater harvesting facilities are relatively small incremental investments that require only the expenditure of resources needed to serve development actually being installed, freeing considerable resources for alternate investments.
- The cost and timing of the large-scale infrastructure installation is typically out of the developer's (and the eventual users') control, as would be the cost of water obtained from that system. The cost and timing of the building-scale facilities are entirely within the users' control, and the on-going cost of water would be low *and* would not be prone to escalation.
- In the large-scale system, treatment problems, line breaks, etc., would have broad ranging impacts, with unpredictable costs to the users. In the micro-scale system, any problems would be isolated and amenable to remediation by individual users and/or the local operating entity. Thus, from a certain viewpoint, the micro-scale system is *more* reliable than the large-scale system.
- A water supply system predicated upon rainwater harvesting within the project is an inherently more sustainable strategy in terms of water resources management than any other option, since the development would in large measure live on the water that falls upon it. This would engender a conservation ethic and stimulate pursuit of efficiency strategies (that would enhance sustainability of water supplies) which may not appear cost efficient—and thus would be retarded—once there is a large sunk cost in a piped water system.
- The water supply from a building-scale rainwater harvesting system would be of higher quality than would be obtained through a piped water system. Rainwater is soft and "pure", being polluted only by materials that may have been deposited on the roof since the last rain. In the large-scale rainwater harvesting systems, there is no control of the collection area, so the storage tank receives water of random quality, including whatever pesticides, fertilizers, and other pollutants that wash off the land, so may require treatment to attain potable quality. Also, the large-scale delivery system requires that the treated water be heavily chlorinated. All this results in the water that is delivered to the points of use being degraded relative to the original quality of the rainwater.
- That large-scale treatment system and that far flung distribution system entail considerable demand for increasingly expensive energy. Typically, pumping water is the number one demand for energy among municipal operations. A point of use treatment and pressurization system would demand far less energy, and would thus entail considerably lower operating cost.

The impact of rainwater harvesting on the stormwater management problem is also a significant factor to consider. Direct rainwater catchment and sequestration can play a significant role in stormwater management. The building-scale rainwater harvesting system would be more efficient in converting rainfall into water supply than would the large-scale systems. A USGS study reported that more than 80%

of rainfall in this area is lost to evapotranspiration, implying that in a large-scale system, only a small minority of total rainfall ever reaches the storage basin. This does not mean that the majority of the rainfall is “wasted” since it is this portion of the rainfall that maintains plant cover in the watershed.

When development occurs, much of the rainfall onto impervious surfaces is converted into quickflow, exacerbating flooding and channel erosion. When a significant portion of a watershed is developed, this would severely decrease the volume of recharge and baseflow, which can negatively impact on the riparian environment and downstream water uses. Indeed blunting these impacts is a major thrust of stormwater management rules which may govern a project.

In the building-scale rainwater harvesting system, the rooftops used as catchment – typically a very significant fraction of total impervious cover – capture and sequester a very high percentage of the rainwater falling on them. So besides providing a water supply, this catchment and storage prevents a significant portion of the additional quickflow imparted by development from occurring. Especially when coupled with a wastewater system which utilizes effluent for landscape irrigation (as outlined in papers under “The Tools of the Decentralized Concept” on this web site), the captured rainwater—which becomes that effluent after serving interior water uses—can even more efficiently perform its plant maintenance function, and some of this irrigation water may percolate to contribute to aquifer recharge and maintenance of baseflow. All this creates a more integrated complex of water management functions, and this enhances the overall sustainability of water resources.

Regarding the need for backup supply, a modeling procedure developed by David Venhuizen, P.E., is used to evaluate the situation. (That model is reviewed in another document in the “Rainwater Harvesting” menu of this web site.) The model is run using 20 years of historical rainfall data from weather stations near the project site. Presuming that future rainfall patterns would not markedly depart from those experienced in that historical period, this can be used to predict the expected shortfall in supply that may occur, given the roofprint (collection area), the cistern (storage) volume, and the demand to be supplied. This modeling shows that precluding need for *any* backup supply under even the most severe conditions would require significantly larger facilities than would be required if the aim was only to limit backup supplies to a “minimal” level.

For this rainwater harvesting strategy to be “practical”, the need for backup supply must indeed be infrequent and limited to a “minimal” level. This would demand more careful attention to water use and management than may be required of users on a typical piped water supply, which may be deemed a marketing liability, as reviewed below. Again, however, this very need to modulate demand would urge and bolster all manner of water resources sustainability initiatives, activities that may otherwise not seem worthwhile.

As for marketing impacts, the fiscal viability of a development-wide building-scale rainwater harvesting system relative to the other available options would be a major determinant of marketability. This entails investigating the cost of the large-scale system infrastructure plus the charge for water vs. the incremental costs to provide building-scale collection, storage and supply facilities and the cost of a reliable system to provide backup supply. All these factors must be studied, in the context of each project, to evaluate the marketability, from a fiscal standpoint, of the building-scale rainwater harvesting water supply strategy, and to elucidate the characteristics of the development that would favor or diminish that strategy.

Another aspect of marketability is perception. Relying on building-scale rainwater harvesting for water supply may be a marketing issue simply because it is not currently the norm, and people fear the unknown. The degree of concern would probably depend on the arrangements made for an assured backup supply, as that would likely be the greatest concern to those who buy into this project and to their lenders. This again highlights the need to evaluate the backup supply strategy.

Potential buyers may also be concerned about holding down water use to keep their backup demand in check. As noted, it would be this very need to modulate demand that may urge and bolster investments in water use efficiency to control water use. This issue should be studied to evaluate the "reasonableness" of attaining the demand rates that appear to be required, based on the modeling and evaluation of backup supply strategy. Relative to sustainability issues, the concept of turning this need into a "badge of greenness" for the project can also be considered as a marketing issue. This may entail consideration of how LEED and Green Builder standards might relate to this overall water management strategy.

As long as there is an assured backup supply system, drought can be addressed just as well as it is in any other type of water supply system. Although curtailments might be urged to minimize backup supply, *all* water systems in Central Texas routinely impose use restrictions during droughts. Typically these drought contingency plans require curtailment of irrigation use. As noted previously, when the rainwater harvesting system is coupled with a wastewater system that irrigates the reclaimed water to defray landscape irrigation demands, the restrictions required in this system could be considerably less compromising. These are other aspects of marketing to be considered.

Another marketing issue for a mixed use development is what impact on fire insurance rates the lack of a piped water system might have. This may indeed be the issue which determines whether a rainwater harvesting strategy is "practical". An open question is if there being multiple cisterns in the immediate area – each with an indeterminate amount of water in it at the time a fire breaks out – would be a "sufficient" substitute for a piped water supply that can provide a designated "fire flow".

As noted, the fiscal viability of a development-wide building-scale rainwater harvesting system relative to a supply from a conventional water utility would be determined by comparing the infrastructure and water costs of that system with the incremental costs to provide building-scale facilities and the cost of a reliable backup supply system. As noted above, attempting to estimate the cost of infrastructure that would be designed in to buildings and associated structures when that development is presently undefined is, however, a highly questionable endeavor.

To begin, the level of supply that must be provided may be open to question. Estimates are "typically" based on a presumption that an LUE (living unit equivalent) generates a demand of 350 gallons/day (gpd). This may be the number that the project principals are required to use when planning for a piped water system, but it is not an accurate estimate of typical residential interior water usage. For example, wastewater system permits for Central Texas developments are being based on a generation rate of well less than 300 gpd. This also leaves open the level of demand for irrigation, and of course how much of that demand would be defrayed by reclaimed "waste" water.

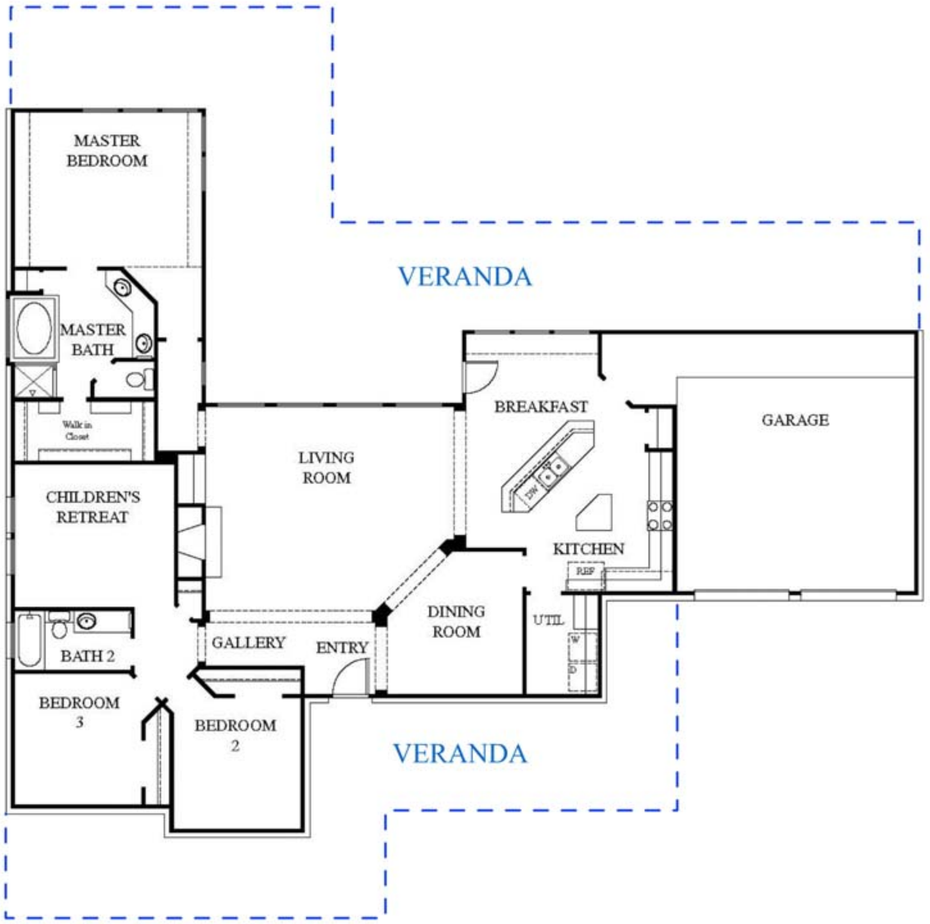
For retail land use, the level of demand would depend greatly on the actual activities in these buildings, in particular how much of the retail would be restaurants. For example, in one case the estimate of water demand by the retail land use supposed a usage rate of (14,000/80,000 =) 0.175 gpd/sq. ft. Using "typical" flow estimates, a restaurant might create a ratio of about 0.7 gpd/sq. ft., while a store might create a ratio of less than 0.1 gpd/sq. ft. If some of the retail were to used for offices, as suggested by new urbanist designs, these would create a ratio of about 0.02 gpd/sq. ft. Thus the retail water demand may be somewhat below the estimate provided. If these uses were to be housed in multi-story buildings, the ratio of water demand to *roof* (water collection) area would increase – e.g., the ratios quoted above would double for a 2-story building. So building design choices may also impact on this matter.

Given such uncertainty in the actual demand to be supplied, a project would have to be rather explicitly defined in order to evaluate a building-scale rainwater harvesting water supply strategy for commercial centers. However, modeling indicates that, except for restaurants and uses with similarly high water use ratios, building-scale rainwater harvesting might provide a very high percentage of total water demand.

The situation for a single-family home is reviewed here, offering an overview of the cost factors in this setting. This residential analysis presumes a roofprint of 4,200 sq. ft. and a cistern volume of 30,000 gallons. Whether these are “too large” depends on the style of houses to be built in the development. While “rain barns” to obtain the required roofprint and free-standing cisterns for storage could be used, it is suggested that this much roofprint and cistern volume could be integrated into the house plan by adding a veranda around, at most, three sides of the house, leaving the fourth side open for the air conditioner condenser and utility line entries. A 30,000 gallon cistern would be accommodated by a containment only about 4 feet deep under the veranda. This creates a “Central Texas rainwater harvesting vernacular” house design concept.

The house plans of a builder active in Central Texas were examined to determine that at least 4,200 sq. ft. of total roofprint could readily be provided using this “veranda strategy”. An example of such a house plan is shown in the figure below. (It is to be expected that house plans generated on this concept from the start could even more efficiently encompass the required roofprint.) This arrangement could be readily accommodated without significantly altering the builder’s processes and specifications – it would entail only additional concrete structures outside the base building envelope and adding on porch roofs. The additional cost of this veranda should be at least partially offset by the value of the sizable outdoor living spaces added onto the house, spaces which are useful over a large portion of the year in this climate. The veranda roof would also provide shade around part of the house perimeter, which would enhance the energy efficiency of the house.

The demand presumed in the analysis is 200 gallons/day, which is 4 persons using 50 gallons/day, or 5 persons using 40 gallons/day. These occupancies are considered the norm for a 3-bedroom and a 4-bedroom home, respectively. (Demographics of most Central Texas developments show that occupancy is typically somewhat lower than 4 persons/household, but of course the system needs to be designed to accommodate the house capacity.) People who design and install rainwater harvesting systems to serve as whole-house supply report that they routinely use as little as 35 gallons/person/day as a planning number. Again, pursuing rainwater harvesting as a water supply strategy would entail the users being aware of the value of water and acting accordingly. The degree of such care required to attain the demand rates deemed to be necessary to make the rainwater harvesting scheme cost efficient is a matter to be considered.



"VERANDA STRATEGY" FOR RAINWATER SYSTEM DESIGN

The results of the "base run" of the model under which rainwater is used only for interior water demands, employing rainfall data from the Austin weather station, indicate that backup supply would have been required in 4 of the 20 years covered by the model (1987-2006). The total amount of backup supply that would have been required over those 20 years was 22,000 gallons. 8,000 gallons would have been required in one year, 6,000 gallons in one year, and 4,000 gallons in the other two years. (Note that the model presumes backup supply is provided in 2,000-gallon tank truck increments, so the modeled backup supply will always be in multiples of that quantity.)

In another run of the model, it is presumed that when cistern volume drops below an "alarm" level of 4,000 gallons, the users would "tighten their belts" and reduce their usage to 80% of the nominal presumption. In this model run, backup supply would have also been required in 4 years, but the total amount of backup supply over 20 years would have been only 10,000 gallons. 4,000 gallons would have been required in one year, and 2,000 gallons would have been required in the other three years.

This illustrates how an "enhanced conservation ethic" among the users would significantly benefit the overall supply strategy. In any case, this equates to the behavior that is urged by drought contingency plans that all water suppliers are required to enforce. In this case, the users are simply more motivated to indeed manifest that behavior. This can be further reinforced by pricing of the backup supply. As reviewed below, it is envisioned that it would be delivered by tanker truck, so the cost would be relatively high in any case – and noting the likely escalation of transport fuel cost in the near future.

The cost factors incurred to provide this water supply include the veranda roof, the cistern, water treatment and pressurization facilities, and the backup water supply system. The cistern top deck would be the floor of the veranda, leaving just a porch roof to complete the veranda. The “base” size of the houses would impact on how large of a veranda area would need to be added, so the target market of the project needs to be determined in order to conduct a meaningful cost analysis. In any case, it would certainly be a small fraction of the base cost of the house. These costs can be determined by consultation with engineers, architects, builders, and construction tradesmen.

The building-scale rainwater harvesting system, as envisioned here, would not include any waterlines through which a backup supply could flow to each house – it is the elimination of this cost that provides the incentive to invest instead in the building-scale supply facilities. Therefore, the presumed backup system would consist of a fleet of tank trucks and a contract assuring water availability from a potable source. This may be a municipal supply system, or a well and storage tank on the property that is used only for this purpose (if indeed a well with sufficient yield could be drilled on the project property).

The major problem with this concept is that when backup supply is needed, most likely just about every house would need it. In one example, there would be 400 single-family homes at buildout. If every house needed a truckload in a given month, and assuming there are 22 work days in a month, this would generate about 18 truck trips per day. Assuming each truck could make 6 trips per day, there would need to be 3 trucks available. Unfortunately, unless some other use could be found for these trucks, a use which could be suspended at will so they could be dedicated to providing backup water supply, they represent an investment that would lie idle most of the time. However, since the houses would be built over a number of years, it is an investment that can be phased.

In summary, while arguments can be made that a building-scale rainwater harvesting water supply strategy may be superior to and more sustainable than extending service from a conventional large-scale rainwater harvesting system—again, that is exactly what the conventional water utility system is—and/or may be a cost and resource efficient adjunct to a piped water system, any comparison of costs and other factors must be developed based on a more detailed knowledge of the specifics and the desired pace of each project. Given the potential benefits of the building-scale strategy, the investment in planning and engineering to establish this information appears worthwhile to consider. But that is an evaluation which the principals of each project must make, based on the criteria that matter to them.