Engineering Technical Memorandum
On
Town of Oro Valley
Water Harvesting
Theory, Quantification and Implementation

Purpose

Rainwater harvesting is defined as intercepting, catching, storing, diverting or directing storm water runoff from roofs, parking areas, etc. during rain events and putting it to beneficial use. The primary recipient of water harvesting is site landscaping.

Criteria

Water harvesting shall be utilized to offset the resource demand placed on the public water supply used for irrigation of site landscaping. Water harvesting may be accomplished by the application of passive or active collection systems.

1. Types of Systems

   a. Passive System:

      Diverts or directs rainwater runoff to appropriate locations where it is collected and allowed to infiltrate the soil naturally. This system contains no long-term storage capabilities.

   b. Active System:

      This type of system employs a reservoir or other water storing apparatus to catch and store rainwater for later use with conventional landscape irrigation systems. It typically involves electric pumps and valves, and will be cross-connected to the site irrigation system.

2. Water Budgeting

   Water budgeting shall be in accordance with the criteria set forth in section 11.3.5 of the Town of Oro Valley Drainage Criteria Manual:

   > Along with detention thresholds, water budgeting must also be completed and presented in the drainage report. The water budget shall show that down-stream habitat will not be inadvertently starved of its pre-developed conditions runoff resources while providing the detention function for the project
   >
   > Water budgets provide a basis for assessing how natural or human-induced change in one part of a hydrologic cycle may affect other aspects of the cycle. As a part of

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the detention hydrology calculations, water budgeting must be implemented to demonstrate that not only is there an adequate reduction in peak storm water discharge for the developed condition, but that excessive amounts of water are not being withheld through site detention and thus starving down stream habitat.

a. The pre-developed conditions storm water discharge rates for the 2 and 10 year storms match the developed conditions within the following criteria:

Existing outflow ≥ Developed outflow ≥ 10% max reduction in Existing outflow

b. The developed conditions storm water volume may not be decreased from pre-developed volumes for the 2 and 10 year storm events. An increase in storm water volume may be accepted as long as there are no downstream drainage facilities that would be adversely affected.

c. The developed conditions storm water discharge points and patterns shall be as similar as possible to those of the pre-developed conditions. This "water balancing" approach is intended to preserve, as closely as possible, existing downstream flow characteristics following proposed development

Reductions in detention requirements will not affect the overall site water budget requirements.

3. Standing Water

a. Standing water for passive water harvesting systems must infiltrate or dissipate within 12 hours of initial ponding.

b. Active water harvesting systems by definition shall be able to store water for future use. All active water harvesting storage systems must be enclosed, covered and mosquito proof.

4. Water quality

All water collected and utilized for water harvesting from parking lots must meet the same discharge quality as stipulated within The Town of Oro Valley Drainage Criteria Manual, section 11.7 – First Flush Requirements.

5. Reduction in Detention

Detention volume may be reduced at a 1:1 volumetric ratio to the volume utilized for water harvesting. This volumetric ratio must be confirmed for the 2-, 10-, 25- and 100–year storm events.

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Water Harvesting Calculation Theory

By definition, detention will return the pre-developed water volumes to affected areas by either infiltration or outflow or more likely a combination of the two. But water harvesting will actually remove this resource permanently from the surrounding eco-system. In order to maintain the integrity of the water budgeting criteria above and not starving down stream habitat or water table recharge, a more defined and detailed approach was implemented than just addressing the larger 2 and 10 year detention approaches.

Historical precipitation data gathered from local Pima County rain gauges to analyze and establish actual volumes of water received by the Oro Valley area:

Study Year	2007	2008
Number of Rain Events	34	44
Total Yearly Rainfall Depth (in)	12.64	14.27
Total Yearly Rainfall Depth (ft)	1.05	1.19

Thus creating a total yearly volume (analyzed per acre) of:

Study Year	2007	2008
Volume in acre-ft/yr	1.05	1.19
Volume in cu-ft/yr/acre	45,883	51,800
Volume in gal/yr/acre	343,206	387,464

And an average depth and volume per storm event of:

Study Year	2007	2008
Depth per Rain Event (in)	0.37	0.32
Volume in cu-ft/storm/acre	1,350	1,177
Volume in gal/storm/acre	10,098	8,806

The above chart, averaged over the 2 study years would render a volume:

½ x (10,098 gal/storm/acre + 8,806 gal/storm/acre) = 9,452 gal/storm/acre

From HEC-HMS analysis of existing sites and associated hydrology reports, the following assumptions were established to create a conservative method of understanding the amount of water that could be removed from the local eco-system and utilized for water harvesting:

a. Approximately 40% of the precipitation falling on to a site remains while 60% runs off feeding off-site habitat in a 10 year event storm. Since the 10 year storm event is larger than the majority of the historical events analyzed, it will be conservative to apply to this retention ratio to the study.

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Caveat: The above statement is based on averaging different sites studied. This ratio is primarily dependant on site shape, topography and geology of the underlying soil. Again, because every site is unique, conservative err is to provide benefit for the down stream habitat and the water table. Notably, smaller storm events will retain larger ratios of the overall storm generated volume.

b. Pavement, buildings and hardscape will absorb approximately 10% of the precipitation that directly falls on them.

Applying the assumptions stated above, the volume for water harvesting shall be established as the additional available volume created by post development impervious surface run off, less what would have run off undeveloped. Or in other words, it is the difference between pre and post development run-off volumes.

Analyzing a one acre site:

- Pre-development runoff = 60% x 9,452 gal/storm/acre = 5,671 gal/storm/acre
- Post-development runoff for a completely developed site (100% asphalt, hardscape & buildings) = 90% x 9,452 gal/storm/acre = 8,507 gal/storm/acre
- Available volume for water harvesting:

  = 8,507 gal/storm/acre - 5,671 gal/storm/acre = 2,863 gal/storm/acre in this completely developed scenario.

<u>Quantification</u>

In association with the theory presented above and the overall intent of the detention water budgeting, the following equation may be utilized to calculate water harvesting:

$V_{WHgal} = \sum A_{IS}$ x 3000gal/acre

Where: V_{WHgal} = Volume of Water Harvesting in gallons

$\sum A_{IS}$ = Summation of impervious surface areas including:
All pavements
Sidewalks
Hardscape elements
Buildings

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Design

Water harvesting basins and facilities shall be designed such that they easily and practically facilitate the use of stormwater runoff to supplement other sources of water in maintaining natural and landscaped vegetation.

1. The maximum depth of any open passive water harvesting basin shall be 4" maximum.

2. Water harvesting basins may be combined with site detention basins provided that the residual ponding will dissipate within 12 hours. This shall be demonstrated by a combination of percolation, evapotranspiration and positive outflow device such as a metered pipe. At a minimum, a positive outflow pipe shall be installed no higher than 4" above the basin invert.

3. All open landscape areas graded less than 1.0% positive outflow slope shall be considered water harvesting areas and be subject to the access and maintenance criteria set forth in the Town of Oro Valley Drainage Criteria Manual, section 11.8.4

4. No passive water harvesting areas shall be allowed within 10 feet of a building or vertical structural element greater than 4' in height without special structural consideration and design approved by the Town Engineer and the Town Building and Safety official.

5. All active water harvesting systems which connect to a potable water supply must have backflow protection installed and meet the requirements of Article 15-23 of the Town of Oro Valley Town Code: Backflow Prevention and Cross-Connection Control Program.

6. Refer to the City of Tucson's Water Harvesting Guidance Manual, Ordinance Number 10210, for design techniques and information. The use of the techniques contained within this manual are subject to the design parameters set within this section of the Drainage Criteria Manual.

Access and Maintenance

Thorough, routine maintenance is required to ensure adequate performance for the life of proposed water harvesting facilities. The drainage report and landscape plan shall address the following:

1. Access is to be provided to all water harvesting basins, appurtenant structures and facilities. Access is to be clearly delineated on the grading and landscape plans. The access shall be located so as to provide minimal disturbance to the site vegetation.

2. Inlet and outlet structures are to be kept free of vegetation and debris at all times.

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3. Vegetation irrigation and maintenance schedules shall be provided as an appendix to the drainage report and in tabular or note form on the landscape plan.

4. The maintenance schedule and requirements shall be detailed in private Covenants, Conditions and Restrictions (CC&Rs). The Homeowner's Association (HOA) or responsible party shall be clearly identified within the CC&Rs and shall be responsible for maintenance of basins and water harvesting appurtenances, and maintenance record keeping. Maintenance records shall indicate:

    a. Date of maintenance activities;

    b. Description of maintenance activities;

    c. Photographs of the basin and appurtenances before and following maintenance activities;

    d. Signature of responsible individual (i.e. HOA President) certifying that the noted maintenance was completed according to the approved schedule and requirements, and that the basin(s) and appurtenances substantially comply with the approved improvement plans; and

    e. Maintenance records shall be retained by responsible party for three years following the most recent maintenance activity. The maintenance records shall be provided to the Town of Oro Valley on a yearly basis.

5. Subject to the Town Engineer's written approval, basin maintenance schedules and requirements may be modified following a three-year period of operation. Supporting documentation for such a request is to include, at a minimum:

    a. Past maintenance records and photographs spanning the previous three years (if applicable);

    b. Current photographs of the basin and basin appurtenances;

    c. A written explanation for the request to modify the maintenance requirements.

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Hydrologic Analysis of Above Theory

The above methodology has been analyzed technically against Rational Equation Calculation of pre vs. post discharge flow volumes. Both the two (2) and ten (10) year events are calculated below to corroborate that the harvesting of 3000 gal/storm/acre is less than the standard statistical rain events analyzed for detention requirements.

1. Volume Produced for the two (2) year, 1 hour rainfall event:

   Q = CiA where:

   Q_e = site discharge prior to development – Pre condition

   Q_p = site discharge of developed impervious surface

   Q_{wh} = available discharge that can be retained for water harvesting

   A = 1ac (assumed acreage for this example for both Pre & Post)

   T_c = 5min (assumed discharge time of concentration for both Pre and Post conditions)

   i = 5in/hr (TOV IDF 2 year rainfall intensity)

   C_e = 0.15 (calculated below using TOV/ADOT method and set as an average of NRCS soil types B and mixed b 50% & C 50%)

   $$P_{2,1hr} = -0.011 + \frac{0.942(P_{2,6hr})^2}{P_{2,24hr}} = -0.011 + \frac{0.942(1.55")^2}{1.90"} = 1.19"$$

   Use $P_{2,1hr}$ = 1.2" (rainfall depth for TOV 2 year event)

   $C_{e,B\ soil}$ = 0.12

   $C_{e,B50/C50}$ = 0.50(0.12) + 0.50(0.23) = 0.18

   C_e = 0.50(0.12) + 0.50(0.18) = 0.15

   C_p = 0.91 (for rainfall event depth of 1.2" and total development of impervious surface – Buildings, hardscape and paving)

   $Q_e = C_e iA$ = 0.15(5in/hr)(1ac) = 0.75cfs

   $Q_p = C_p iA$ = 0.91(5in/hr)(1ac) = 4.55cfs

   $Q_{wh} = Q_p - Q_e$ = 4.55cfs – 0.75cfs = 3.80cfs

   Volume retained from PCHydro V5.3.1 model analysis = 0.0793af = 25840gal

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2. Volume Produced for the ten (10) year, 1 hour rainfall event:

   Q = CiA where:

   Q_e = site discharge prior to development – Pre condition

   Q_p = site discharge of developed impervious surface

   Q_{wh} = available discharge that can be retained for water harvesting

   A = 1ac (assumed acreage for this example for both Pre & Post)

   T_c = 5min (assumed discharge time of concentration for both Pre and Post conditions)

   i = 7in/hr (TOV IDF 10 year rainfall intensity)

   C_e = 0.38 (calculated below using TOV/ADOT method and set as an average of NRCS soil types B and mixed b 50% & C 50%)

   $P_{10,1hr} = 0.496(P_{2,1hr}) + 0.449(P_{100,1hr})$

   $$P_{2,1hr} = -0.011 + \frac{0.942(P_{2,6hr})^2}{P_{2,24hr}} = -0.011 + \frac{0.942(1.55'')^2}{1.90''} = 1.19''$$

   $$P_{100,1hr} = 0.494 + \frac{0.755(P_{100,6hr})^2}{P_{100,24hr}} = 0.494 + \frac{0.755(3.70'')^2}{4.70''} = 2.69''$$

   $P_{10,1hr}$ = 0.496(1.19”) + 0.449(2.69”) = 1.79” – use 1.8”

   $C_{e,B\ soil} = 0.34$

   $C_{e,B50/C50} = 0.50(0.34) + 0.50(0.47) = 0.41$

   $C_e = 0.50(0.34) + 0.50(0.41) = 0.38$

   C_p = 0.94 (for rainfall event depth of 1.8” and total development of impervious surface – Buildings, hardscape and paving)

   The difference between the C_p and the C_e is the basis of logic in the theory presented above. Essentially 0.94 – 0.38 = 0.56, or rounded off as 40% of the flow remains on site while 60% runs off. This is important factor in maintaining the hydrologic balance of the desert.

   $Q_e = C_eiA = 0.38(7in/hr)(1ac) = 2.66cfs$

   $Q_p = C_piA = 0.94(7in/hr)(1ac) = 6.58cfs$

   $Q_{wh} = Q_p - Q_e = 6.58cfs – 2.66cfs = 3.92cfs$

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Volume retained from PCHydro V5.3.1 model analysis = 0.0957af = 31184gal

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