Developing a Net-Water Positive Vision for the Sierra Vista Subwatershed

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Contents

Background

This report is an exploration of the potential that can result from shifting a community's water resource paradigm. This paradigm shift has already begun and has made strong gains in collaboration, innovation, science-based management, and most importantly community values related to water resources and protection of our heritage of a flowing river – the San Pedro River. This analysis is meant to compliment ongoing efforts to develop a holistic strategy that can provide near-term protection of San Pedro River flows and a secure long-term water supply from the regional aquifer.

A naturally flowing river is an indicator of watershed health and community health. Beyond the ecosystem service values a river provides ultimately it is a barometer of water security and future fate of a community. A river connected to groundwater indicates a water balance and sustainable yield of water available for and shared by all users.

The Sierra Vista Subwatershed greater community stands at a crossroad after decades of positive steps. One path leads to continued slow measured gains to better management of water resources yet inevitable decline of San Pedro River flow its benefit to the community. Another path leads to accelerated steps to reduce groundwater demand and enhance recharge to achieve a water positive balance and sustain future flow in the San Pedro River while creating a thriving and diverse regional economy.

Timing is critical. The probability of a positive outcome for the river and the community rapidly diminishes the longer we take to achieve a water positive balance. This report outlines a strategy framework, water resource targets, and supporting actions for success and the future vitality and resilience of the communities supported by a flowing San Pedro River.

Protecting perennial flow in the San Pedro River by restoring aquifer health is possible through increased indoor water efficiencies, reduction of outdoor consumptive water use, and strategic enhanced recharge of the regional and near river groundwaters across the Sierra Vista Subwatershed. An array of watershed stakeholders have been dedicated to advancing water conservation efforts and improving river health for decades. These efforts have resulted in a significant and an on-going shift towards "water neutral" for the greater subwatershed[1]. However, to address long-term impacts created by groundwater pumping resulting in a cone of depression under the City, Sierra Vista and subwatershed neighbors will need to achieve a "water positive" status by returning more water to the regional and near river aquifers than is extracted. The opportunity for future sustainable project investments to become water positive can be driven by market forces, incentives, and long-term funding mechanisms.

From a water demand perspective the Sierra Vista Subwatershed has a 2018 estimate of 72,870 residents[2] and an estimated annual water balance deficit of 5,050 acre feet. This deficit is equivalent to 62 gallons per capita per day over a balanced consumption rate. The current estimate of total per capita demand is 155 gallons per person per day. Is it feasible to reduce per capita use to 93 gallons per day or even lower as population increases?

For comparison Australian residential use reduced from 83 gallons per capita (gpcd) in 2000 to 52 gpcd in 2008, a 31 gpcd reduction (37%)[3]. Melbourne, with a temperate climate and summer heat waves, had in 2005 averaged 40 gpcd residential use and 63 gpcd for total urban use. Australian communities are not a perfect comparison to Sierra Vista but provide insight and highlight potential water saving opportunities and mechanisms. Regionally, Tucson Water (Tucson, AZ) residential customers have realized a reduction from 115 gpcd in 2000 (180 total potable gpcd) to 80 gpcd in 2015 (120 total potable gpcd) and Tucson Water expects residential use rates to continue to decline for the coming years[4].

A highlight of a great local success is Sierra Vista's adoption of EPA's WaterSense standards for new home construction. A study by the Alliance for Water Efficiency found an average indoor water use demand for EPA WaterSense homes to be 36.7 gpcd[5]. By shifting landscape practices and utilizing water harvesting it is realistic to achieve 40-50 gpcd and perhaps continue downwards as conservation behavior-based values continue to develop.

The objective of this report is to provide recommendations for how new development can reduce water demands and better utilize urban enhanced runoff to shift towards a water positive future to enable groundwater aquifer stabilization and recovery and support sustained flow in the San Pedro River. An example case study is presented below to describe the range of development scenarios possible and accompanying policy options to promote appropriate development from a water resources perspective.

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[1] Current water balance estimate for the subwatershed is a deficit of 5000 acre-feet per year and a cumulative groundwater deficit of over 800,000 acre-feet as reported by the USGS in 2016 and Lacher in 2017.

[2] Based on moderate growth projections from 2015 to 2050 provided by City of Sierra Vista in August 2017

[3] Cahill, R. and J. Lund, 2011. Residential Water Conservation in Australia and California, https://watershed.ucdavis.edu/pdf/Cahill_Residential%20Water%20Conservation%20in%20Australia, Accessed 17 May 2018

[4] Water Conservation Program FY 2016-17 Annual Report, Tucson Water, 2017.

[5] Water Research Foundation, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

Residential Development Scenarios

WMG engaged a local builder, Workman Homes, to assess the water resource demands and mitigation opportunities for the platted Cañada Vista sub-division, a 92-lot infill project located within the City of Sierra Vista. The build out of the subdivision would encompass 60 acres that includes the area of an ephemeral channel bisecting the development.

Water resources available to the development include pumped groundwater delivered through a water utility, on-site rainfall and stormwater runoff in an ephemeral channel. This analysis determined the potential opportunity of reducing and mitigating pumped groundwater through rainfall and stormwater runoff utilization strategies.

Four scenarios incorporating various low impact development (LID) strategies were developed and compared to the pre-development and existing platted and approved base plan (see Appendix for visual representation and results for each scenario). The first two LID scenarios were essentially two different LID retrofit approaches to the base plan.

Scenario 1 identified extra space to separate from large lots scattered throughout the development to direct stormwater runoff and enhance infiltration with the use of basins and swales. Scenario 2 retained a few of the extra spaces identified in scenario 1 and also applied a street side swale and basin system to capture and infiltrate street runoff. Scenario 3 drastically reduced lot size to create drainage easements which could also serve as common space. The common spaces were configured to enhance walkability of the development and would be planted with native low-water use plants that once established would not receive supplemental irrigation. Scenario 4 reconfigured the entire development into a townhome configuration clustered in fours. This configuration maximized natural open space, included street side swales and basins, and a rainwater tank for each townhome cluster for irrigation use and toilet flushing for each unit.

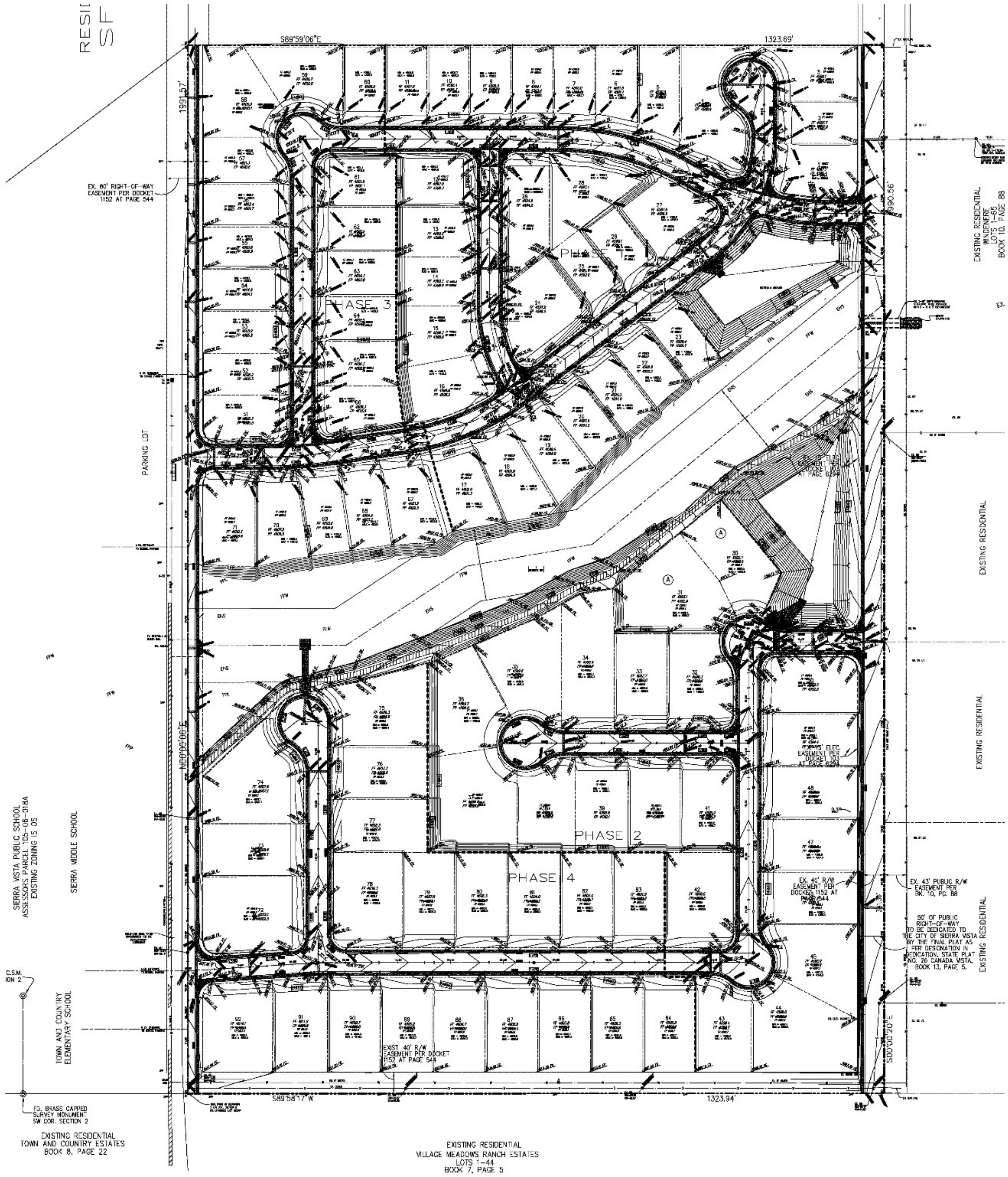


Figure 1. Cañada Vista grading and drainage plan provided by Workman Homes. Note the natural channel splits the development in the middle and receives the runoff from both halves.

Figure 2. The Cañada Vista development overlaid on an aerial photo with adjacent street names.

Runoff Analysis

Stormwater volumes were estimated for both pre-development and post-development conditions. Calculating the difference between modeled pre-development and post-development runoff provides an estimate of the amount of Urban Enhanced Runoff from development (discussed in greater detail below). To estimate annual runoff volumes a historic rainfall event analysis was conducted based on a nearby rain gauge[6] for the previous 33-year record (1982-2015). The recent 10-year historic period of record was selected for analysis. This period had a significant lower mean annual rainfall (13.22") from the 33-year period (14.02") which provides a conservative planning estimate for available annual rainfall volume as a resource.

[6] Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?az7880

Rainfall events were categorized by size to allow for extrapolation from event rainfall runoff volumes to annual volumes. The recent 10-year historic period of records were used as a conservative estimate for this extrapolation as seen in the table below.

Table 1. Rainfall analysis to assess average number of rainfall events by event depth over period of record.

	Number of Average Annual Rainfall Events					
Period of Record	All Rain Events	0.1" < AND ≤ 0.25"	0.25” < AND <= 0.5”	0.5” < AND <= 1”	1” < AND <= 2”	> 2”
1983–2015 Mean	50.5	12.3	9.0	6.2	2.2	0.1
2006-2015 Mean	42.4	10.4	5.8	6.8	2.5	0.1

EPA’s Stormwater Management Model (SWMM) version 5.1 with Low Impact Development modeling capabilities was used to estimate total annual stormwater runoff for each development scenario and the pre-development condition. The original drainage study submitted to the City of Sierra Vista for Cañada Vista was developed by McIntosh & Associates using the rational method to calculate stormwater discharge. The SWMM model developed utilized the results from the McIntosh study to calibrate for pre and post development scenarios for the 10 and 100 year 1 hour storm events, the same events utilized by McIntosh & Associates. The SWMM model parameters for soil infiltration and impervious land cover characteristics were transferred from JE Fuller’s SWMM analysis from WMG’s 2015 Stormwater Action Plan for Sierra Vista report[7].

Daily rainfall events were separated into bins of 0.1-0.25”, 0.25-0.5”, 0.5-1”, 1-2” and greater than 2”. The average rainfall value for each bin was utilized as a storm event in the model. The resulting runoff values were multiplied by the number of storm events occurring within that bin in order to simplify the modeling of annual rainfall. Years were divided into wet, dry, and average years in order to determine the amount of stormwater runoff available in a variety of scenarios and to understand the basic quantity of stormwater that can be expected even in dry years for development supply. Wet and dry years were defined as one standard deviation away from the average as done by Milczarek et al 2005[8]. Scenario 4 was run with actual rainfall data from 1985 with a 24 hr distribution for daily rainfall values. 1985 was determined to be a representative year of “average” data for total rainfall and distribution of rainfall events.

The calibrated model for the base development scenario was modified with LID practices for each of the four different scenarios shown in Table 2. All development scenarios resulted in greater runoff volumes then pre-development conditions. Scenarios 1 & 2 did not result in significant peak flow reductions to the detention basins and Scenario 3 did have a potential peak flow depth reduction of 0.5 to 1 feet.

[7] Watershed Management Group. 2015. A Stormwater Action Plan for Sierra Vista. https://watershedmg.org/document/stormwater-action-plan-sierra-vista and Appendices: https://watershedmg.org/document/appendices-stormwater-action-plan-sierra-vista. Accessed 16 May 2018

[8] Milczarek, M., A. Graham, J Harding, and D. Toy. 2005. Preliminary Assessment of Increased Natural Recharge Resulting from Urbanization and Stormwater Retention within the City of Chandler. 12th Biennial Symposium on Artificial Recharge of Groundwater Conference.

Scenario 4 resulted in a significant potential to turn the detention area facilities into multiuse recreation areas as a result of reducing peak flow depths to within 0.5'.

Table 2. Stormwater runoff characteristics by development scenario assessed for the proposed Cañada Vista development located in City of Sierra Vista.

Scenario	Scenario Type	Number of Homes	Annual runoff estimate (AF)	Peak flow depth estimate for detention basin 1 (FT)	Peak runoff estimate for detention basin 2 (FT)
0	Pre-development	N/A	1.1	N/A	N/A
Base	Platted single-family residential	92	12.9	2.0	3.6
1	Opportunistic Low Impact Development (LID)	93	12.3	1.8	3.5
2	Streets rights-of-way with LID	93	12.2	1.9	3.5
3	Drainage easement with LID	92	9.1	1.5	2.5
4	Clustered townhome with LID	108	8.5	0.5	0.4

Water Budget Analysis

The water demands of the subdivision were calculated using both ADWR's Demand Calculator (rev. 11/24/2015) and inserting various water use restrictions for each development scenario. Based on lot size and census data the calculations assumed an average of 2.32 persons per household. Sierra Vista utilizes EPA's WaterSense standards which has an average indoor demand of 36.7 gpcd[9]. Total annual residential water use also accounted for outdoor low-water use landscaping (per development scenario), lost and unaccounted for water, and construction demand.

The calculated balance in Table 3 is the result of the estimated total annual water use less the return flow of indoor wastewater being received and recharged at the wastewater treatment plant. Recharge at the wastewater treatment plan was assumed to be 80% of indoor water use to account for drinking water, leaks, and wastewater treatment loss. Estimated urban enhanced runoff volume was not factored in the balance but is of interest to compare. Only in two of the scenarios (#3 and 4) does the expected urban enhanced runoff volume exceed the balance deficit for the potential opportunity to shift

[9] Water Research Foundation, http://www.allianceforwaterefficiency.org/residential-end-uses-of-water-study-1999.aspx

towards a net-water positive development with on-site strategies (see Recommendations section following).

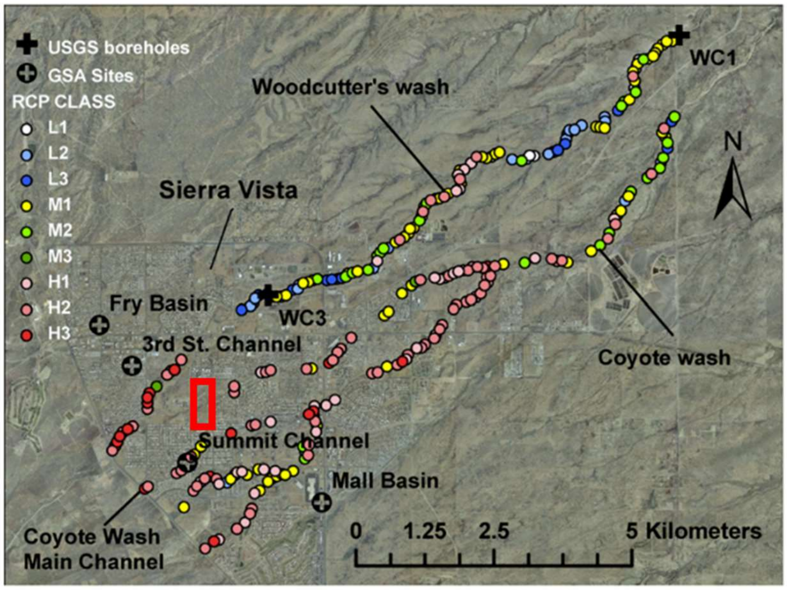


Figure 9 Map of recharge potential in Coyote and Woodcutter's Washes. Red = high (*H*), green = moderate (*M*) and blue = low (*L*) near-surface permeability derived from VCP-σ_a. Shades of color within each permeability category are derived from the six other data types collected. These shades denote magnitude of recharge potential, with paler colors indicating lower recharge potential and darker colors indicating higher.

Figure 3. The Cañada Vista proposed development highlighted (red box) on a map of recharge potential from Callegary et al. 2007 published paper.[10]

[10] Callegary, J.B., J.M. Leenhouts, N.V. Paretti, and C.A. Jones, 2007. Rapid estimation of recharge potential in ephemeral-stream channels using electromagnetic methods, and measurements of channel and vegetation characteristics. Journal of Hydrology. 344, 17-31.

Table 3. Annual water use (in acre-feet (AF)) and urban enhanced runoff estimates by development scenario (see Appendix) for the proposed Cañada Vista development located in City of Sierra Vista.

Scenario	Scenario Type	Number of Homes	Annual Urban Enhanced Runoff (AF)	Annual Water Use (AF)	Annual Indoor Wastewater Treated & Recharged (AF)	Balance (AF)	Assumptions
Base	Existing proposed single-family residential	92	11.8	57.4	9.3	**(48.1)**	Original development proposal with ADWR estimated water use
1	Opportunistic Low Impact Development (LID)	93	11.2	35.8	7.7	**(28.1)**	Assume EPA WaterSense interior, 30 gpcd exterior use, no swimming pools, no turf, low water use large lot adjustment
2	Streets rights-of-way LID	93	11.1	38.3	7.7	**(30.6)**	Assume EPA WaterSense interior, 30 gpcd exterior use, no swimming pools, no turf, low water use large lot adjustment
3	Drainage easement LID	92	8	13.8	7.6	**(6.2)**	Assume EPA WaterSense interior, 30 gpcd exterior use, no swimming pools, no turf; drainage easements provide assurance of LID effectiveness and naturalized landscape requiring minimal irrigation once established.
4	Clustered townhome with LID	108	7.4	9.5	8.9	**(0.6)**	Assume EPA WaterSense interior with toilet (8.2 gpcd) fed by rainwater tank, exterior irrigated by rainwater tank, no swimming pools, no turf; remaining common space with naturalized landscape similar to scenario #3.

Recommendations

The evaluation of Cañada Vista development scenarios surfaced several challenges the community of Sierra Vista will need to address to shift towards net-water positive development. These challenges are:

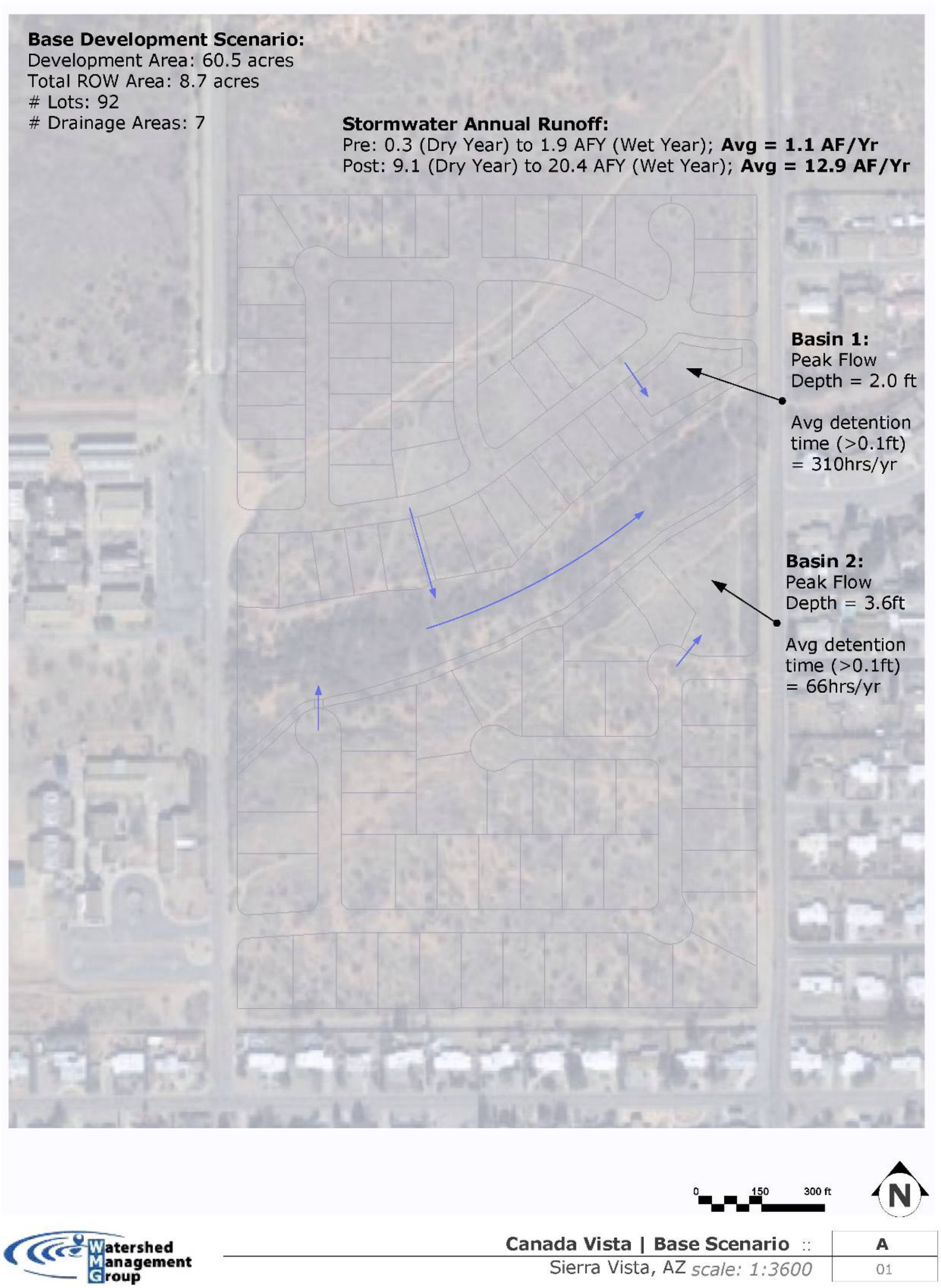
1. The ability to comprehensively integrate low impact development (LID) strategies is limited when "retro-fitting" an existing development plan. Two of the development scenarios (1 and 2) were developed to work within current City of Sierra Vista codes and the constraints of the approved platted development plan. LID in these scenarios was limited to narrow public easement areas only. This led to what are essentially LID "retro-fit" scenarios since we were presented with an already approved development plan.
2. Conventional single family residential development layout is not conducive to ensuring optimal use of rainfall and stormwater. Even if passive and active water harvesting systems are installed at each individual home their performance cannot be guaranteed to serve a flood control purpose or to reduce groundwater pumpage. The third development scenario with drainage easements attempted to overcome this issue by reducing private landscape area and transferring it to common space either under a HOA or city drainage easement.
3. To achieve a net-water positive development requires increased recharge of urban enhanced runoff greater than recharge under pre-development conditions. The limited recharge capacity due to general permeability of Sierra Vista soils will require creative solutions. Four potential solutions to increase recharge of urban enhanced runoff in a development such as Cañada Vista include:
    a. Grade control structures constructed in the downstream natural channel to slow runoff, accumulate sediment, and increase deep infiltration. The difficulty of this option is in the measurement and monitoring to ensure enhanced recharge is occurring. Figure 3 shows that underlying soil conditions may be permeable and conducive to recharge. This option with two grade control structures was estimated to increase recharge potential by 1.7 AF per year[11].
    b. Dry wells located in the two detention basins fitted with a flow meter could facilitate recharge and measure runoff volumes passing through. The feasibility and cost effectiveness of this option depends on underlying soil conditions. The potential to recharge if soil conditions are favorable could exceed 2 AF per year (dependent on actual infiltration rates and duration of retained water in the basin).
    c. Substitution of non-potable indoor water uses with collected rainwater will then flow to the EOP wastewater treatment facility and be recharged near to the San Pedro River. In Scenario #4 the estimate of toilet flushing with rainwater was 2.5 AF per year which approximately 2.35 AF per year would be recharged at the EOP wastewater facility. The cost effectiveness and assurance of longer-term success is better achieved in non-residential settings. Commercial and institutional locations which have larger contributing roof areas and a higher portion of water use being toilets may be a better setting.
    d. Offset pumpage and/or increase recharge off-site. This last option would offset a development's new pumpage demands by facilitating either the reduction of

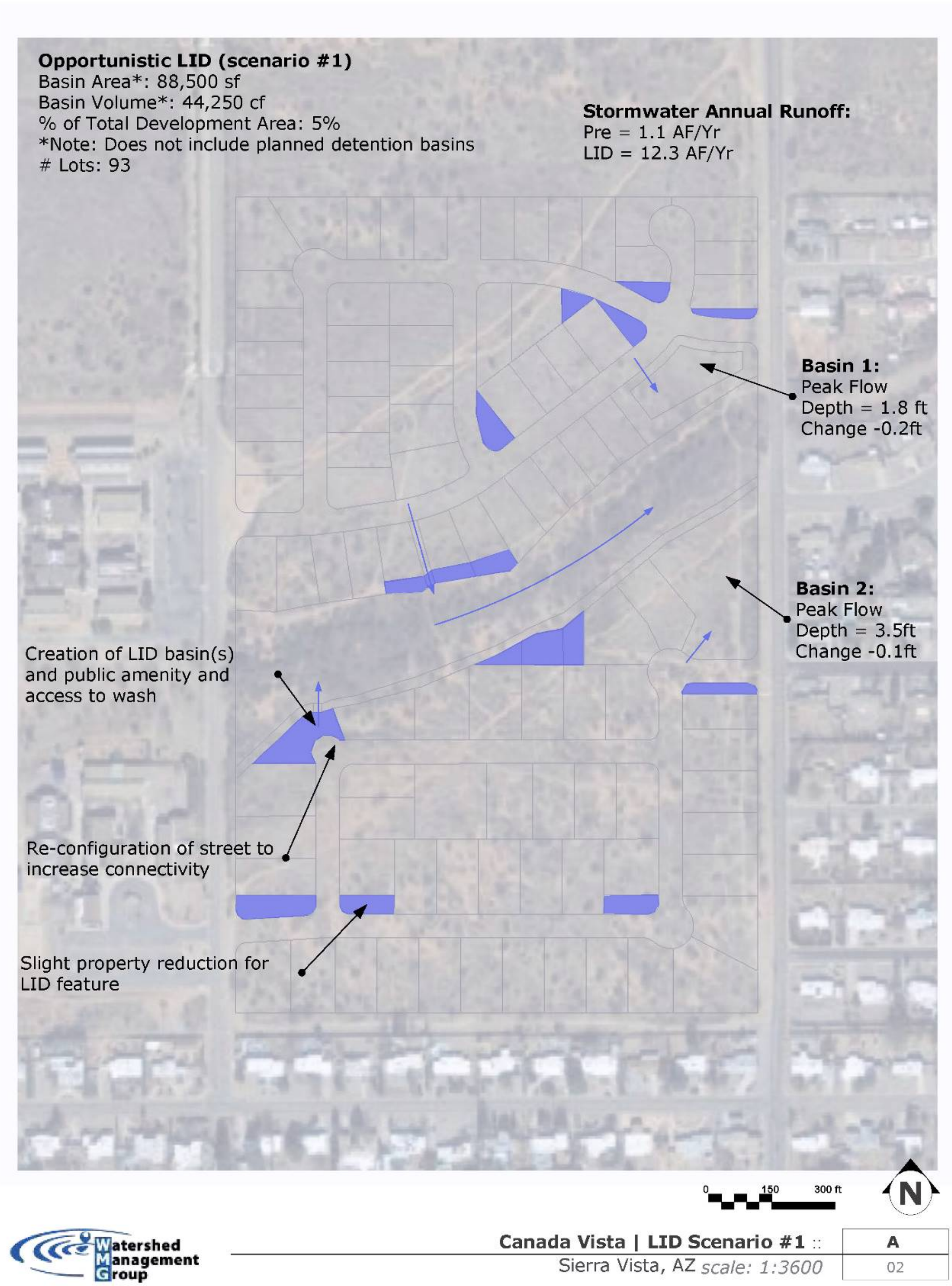
[11] Based on methods used in WMG's 2015 Stormwater Action Report for City of Sierra Vista analysis.

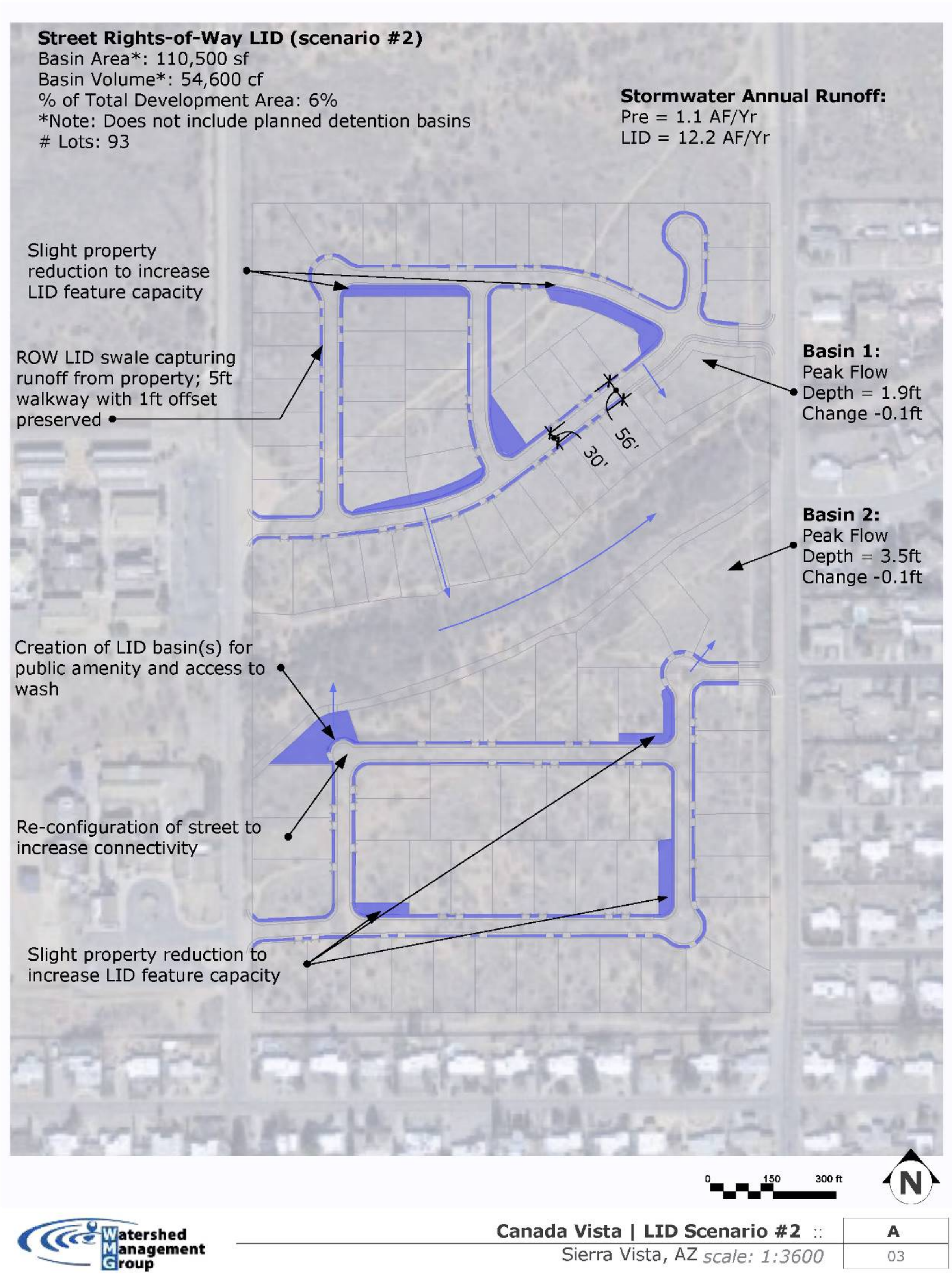
groundwater pumpage and/or augmentation of groundwater supplies through increased recharge of Urban Enhanced Runoff (UER) recharge elsewhere in the watershed. This may be the easiest option for many developments to achieve a net-water positive development as it does not require straying far from the conventional model of development. However, in time the opportunity to achieve off-site impacts will diminish and potentially force significant changes in development practices or end development all-together.

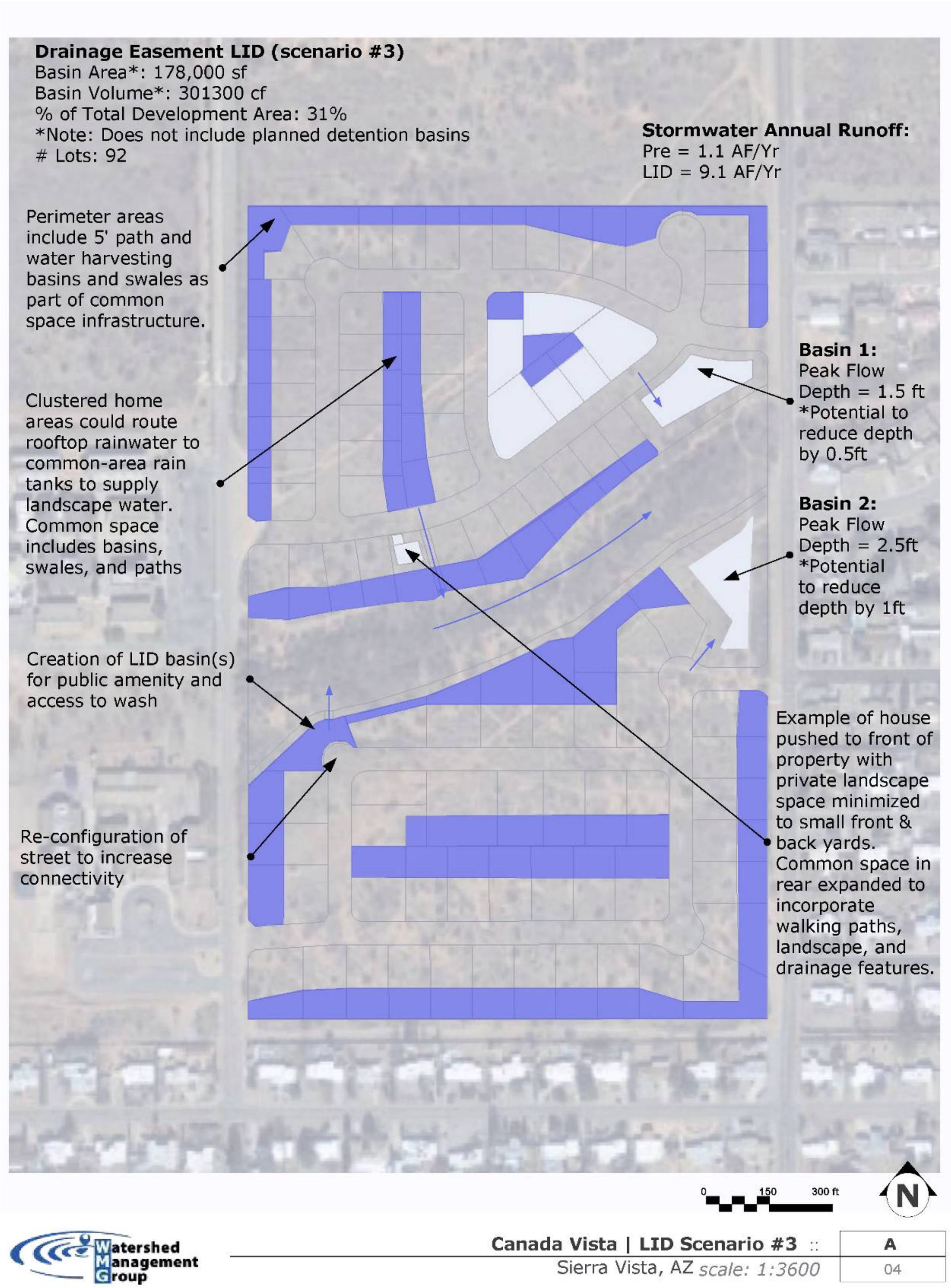
In summary, it is difficult to achieve a net-water positive development with conventional single family models. Determining how to achieve net-water positive development is critical at this point in time if the Sierra Vista Subwatershed's economy can continue to grow and ensure room for growth far into the future. This analysis is meant to compliment the efforts of developing a framework for a comprehensive groundwater pumping mitigation program to ensure continued flow in the San Pedro River as a critical component of the area's economy and as an indicator of watershed health, long-term groundwater security, and ultimately community health.

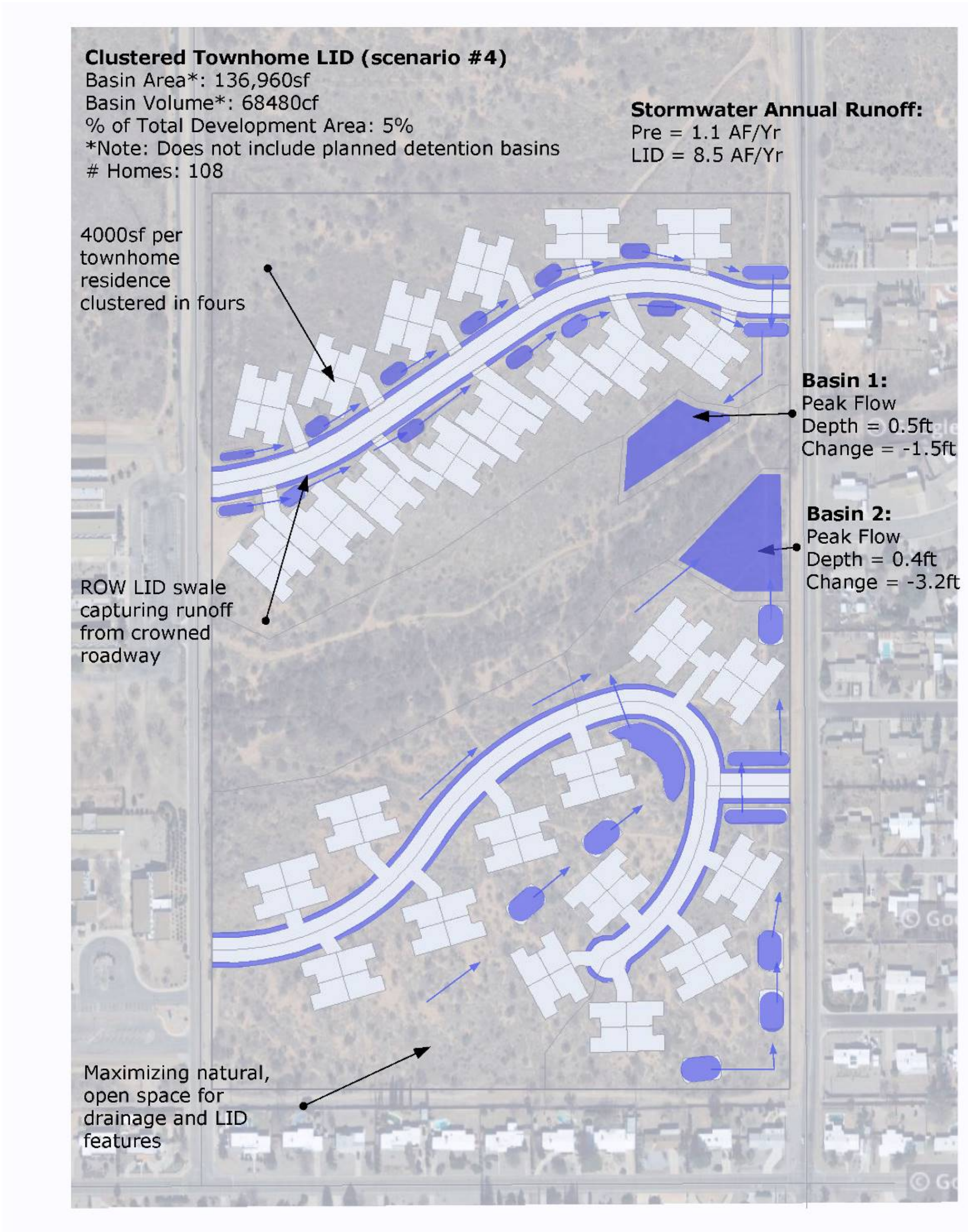
Appendix: Cañada Vista Development Scenarios Evaluated




Opportunistic LID (scenario #1)
Basin Area*: 88,500 sf
Basin Volume*: 44,250 cf
% of Total Development Area: 5%
*Note: Does not include planned detention basins
Lots: 93
Stormwater Annual Runoff:
Pre = 1.1 AF/Yr
LID = 12.3 AF/Yr
Basin 1:
Peak Flow
Depth = 1.8 ft
Change -0.2ft
Basin 2:
Peak Flow
Depth = 3.5ft
Change -0.1ft
Creation of LID basin(s) and public amenity and access to wash
Re-configuration of street to increase connectivity
Slight property reduction for LID feature
0 150 300 ft
N
Watershed Management Group
Canada Vista | LID Scenario #1 ::
Sierra Vista, AZ scale: 1:3600
A
02


Street Rights-of-Way LID (scenario #2)
Basin Area*: 110,500 sf
Basin Volume*: 54,600 cf
% of Total Development Area: 6%
*Note: Does not include planned detention basins
Lots: 93
Stormwater Annual Runoff:
Pre = 1.1 AF/Yr
LID = 12.2 AF/Yr
Slight property reduction to increase LID feature capacity
ROW LID swale capturing runoff from property; 5ft walkway with 1ft offset preserved
56'
30'
Basin 1:
Peak Flow Depth = 1.9ft
Change -0.1ft
Basin 2:
Peak Flow Depth = 3.5ft
Change -0.1ft
Creation of LID basin(s) for public amenity and access to wash
Re-configuration of street to increase connectivity
Slight property reduction to increase LID feature capacity
0
150
300 ft
N
Watershed Management Group
Canada Vista | LID Scenario #2
Sierra Vista, AZ scale: 1:3600
A
03


Drainage Easement LID (scenario #3)
Basin Area*: 178,000 sf
Basin Volume*: 301300 cf
% of Total Development Area: 31%
*Note: Does not include planned detention basins
Lots: 92
Stormwater Annual Runoff:
Pre = 1.1 AF/Yr
LID = 9.1 AF/Yr
Perimeter areas include 5' path and water harvesting basins and swales as part of common space infrastructure.
Clustered home areas could route rooftop rainwater to common-area rain tanks to supply landscape water. Common space includes basins, swales, and paths
Creation of LID basin(s) for public amenity and access to wash
Re-configuration of street to increase connectivity
Basin 1:
Peak Flow Depth = 1.5 ft
*Potential to reduce depth by 0.5ft
Basin 2:
Peak Flow Depth = 2.5ft
*Potential to reduce depth by 1ft
Example of house pushed to front of property with private landscape space minimized to small front & back yards. Common space in rear expanded to incorporate walking paths, landscape, and drainage features.
0
150
300 ft
N
Watershed Management Group
Canada Vista | LID Scenario #3 ::
Sierra Vista, AZ scale: 1:3600
A
04



0 150 300 ft

N

Watershed Management Group

Canada Vista | LID Scenario #4 ::
Sierra Vista, AZ *scale: 1:3600*

A
05

Acknowledgements

We are thankful to Workman Homes LLC for sharing the Cañada Vista development plans for this case study analysis. This analysis and report was made possible with funding from the Walton Family Foundation.

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