A Stormwater Action Plan for Sierra Vista

December 2015

Update: 14 January 2016

Prepared for the City of Sierra Vista by Watershed Management Group

Acknowledgements

The Watershed Management Group team is deeply thankful to Mayor Rick Mueller and City Manager Charles Potucek with the City of Sierra Vista for their interest and support in exploring new potentials in stormwater management to benefit both the community and the environment. City of Sierra Vista staff including Sharon Flissar, Matt McLachlan, Jeff Pregler, Alan Humphrey, Don Brush (retired) and Scott Dooley (retired), and Dan Coxworth (Metropolitan Planning Organization) were critically helpful in providing and sharing data, ideas, and review of concepts and reports. We are also thankful for the key stakeholders who provided time, assistance, ideas, and feedback and included Cado Dailey, Tim Cervantes, Karen Riggs, Rick Coffman, Dan Reeb, Brooke Bushman, Ben Lomeli, Laurel Lacher, Bruce Gungle, and Dave Goodrich.

This Stormwater Action Plan was made possible with funding from the Walton Family Foundation.

Editors: Catlow Shipek, Kieran Sikdar, CFM, and Cidney Jones, P.E., CFM, Watershed Management Group

Contributors: Mark Murphy, R.G., Ph.D., NV5 and Cyrus Miller, P.E., CFM, JE Fuller/Hydrology & Geomorphology, Inc.

Watershed Management Group (WMG), a 501(c)3 non-profit organization based in Tucson, Arizona, develops community-based solutions to ensure the long-term prosperity of people and health of the environment. We provide people with the knowledge, skills, and resources for sustainable livelihoods. We envision a world where the relationship between communities and the environment creates prosperity for all.

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Front cover: A rain garden at McFadden Park, Sierra Vista. Photo Credit: Watershed Management Group.

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Executive Summary

The Sierra Vista sub-watershed drains to the San Pedro Riparian National Conservation Area (SPRNCA) and the City and region are currently withdrawing more water than is naturally replenished each year. This water deficit can be reduced through a holistic view of stormwater management within the sub-watershed. Although this Stormwater Action Plan is specifically focused on the City of Sierra Vista it can serve as a guide for further adoption of Low Impact Development (LID) and green infrastructure practices throughout the Sierra Vista subwatershed. Managing stormwater as a beneficial resource from the individual site to the San Pedro is a promising shift in stormwater management.

This action plan presents concrete steps for Sierra Vista to balance site-based uses of stormwater through LID features as well as geomorphic restoration of urban channels to enhance recharge and preserve base flow in the San Pedro River. This report identifies individual projects and policies that can close the water deficit and improve the long-term health of the San Pedro River, the aquifer and the community.

Analyses of Sierra Vista's urban stormwater potential were conducted to inform the proposed action steps outlined in this report. These analyses included:

- Hydrologic modeling to determine the potential for reductions in stormwater runoff, irrigation needs, stormwater pollution, and erosion,
- Cost-benefit analysis of LID and conventional stormwater management practices that quantifies the potential benefits of LID related to direct and indirect benefits relevant to the City,
- Alternative channel stabilization design using geomorphic channel restoration features,
- Assessment of urban channel geologic and soil conditions to identify enhanced recharge potential throughout the City's arroyos, and
- Review of the City's development code chapters to promote LID in new development.

Hydrologic modeling shows that LID has the potential to meet all on-site irrigation while having little to no impact on downstream flows that reach the San Pedro River. It is possible to utilize LID throughout urban development without impacting the downstream recharge efforts being developed by Cochise County and The Nature Conservancy. Cost benefit analysis results show that for every $1 invested in LID retrofits, over $3-6 of value are created for the community from water conservation, shading buildings and streets, calming traffic and other benefits described in subsequent sections. LID practices show a return on investment of 6-10 years depending on the type of practice and the benefits analyzed. For new development the value created is greater and the time needed for return on investment is decreased. A geomorphic channel restoration approach can provide long-term solutions to enhancing urban wash aesthetics while protecting urban infrastructure, reducing maintenance costs and enhancing recharge. Development code modifications to promote LID can take advantage of the benefits while creating little to no additional cost for development.

LID is a critical tool to address the long-term health of the San Pedro River, the aquifer and the community. Utilizing LID practices in the urban environment and a geomorphic restoration approach in channels, water conservation benefits can be achieved and recharge can be enhanced in order to reduce groundwater pumping and reverse the continued growth of the aquifer's underlying cone of depression. This report provides a summary of analyses and recommendations to promote the advancement of LID use throughout the Sierra Vista sub-watershed.

Introduction

As members of the Upper San Pedro Partnership the City of Sierra Vista (City) is committed to restoring surface flows of the San Pedro River ecosystem. The San Pedro Riparian National Conservation Area is a protected resource that is negatively impacted by groundwater overdraft within the Sierra Vista Sub-watershed.[1] The water withdrawals in the Sierra Vista Sub-watershed exceed the rate of recharge by approximately 5,000 acre-feet of water every year.[2] While this water deficit is shared by the communities within the sub-watershed, it is possible to significantly mitigate this deficit within the City itself. A shift towards valuing stormwater as a resource has occurred at both the individual site level (i.e. water harvesting) and at the sub-watershed level (i.e. Palominas Recharge Project). Current efforts to collect and directly recharge urban enhanced runoff (UER) near the river may conflict with promoting water harvesting practices at individual sites to reduce groundwater demand. Does increased stormwater recharge on the uplands cause a reduction in the ephemeral streamflow reaching the river? The question this action plan attempts to address is – *How do we optimally balance beneficial use of stormwater at the site and along its journey down to the San Pedro River?*

Watershed Management Group (WMG), working with Hassayampa Associates (Hassayampa) and JE Fuller/ Hydrology & Geomorphology, Inc. (JE Fuller) have developed a suite of opportunities outlined in this report to reduce the deficit within the City through management of stormwater as a resource. This stormwater action plan identifies opportunities and benefits of on-site and in-street Low Impact Development (LID) practices paired with geomorphic-based channel practices that utilize stormwater as a valuable resource.

The focus of this plan is primarily how to best tackle the water deficit for long-term health of the San Pedro River while protecting short-term declines in base flow. Our study analyzed the impact LID can have to reduce the demand side of the water deficit while protecting downstream flow outputs for potential use at recharge facilities. In addition we examined potential benefits which may be derived through urban channel enhancements to address both infrastructure/erosion concerns while enhancing channel aquifer recharge.

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[1] Bureau of Reclamation, 2007, Appraisal report—Augmentation alternatives for the Sierra Vista sub-watershed, Arizona—Lower Colorado Region: Denver, Colo., U.S.

[2] http://www.sierravistaaz.gov/water/content.php?fDD=22-247

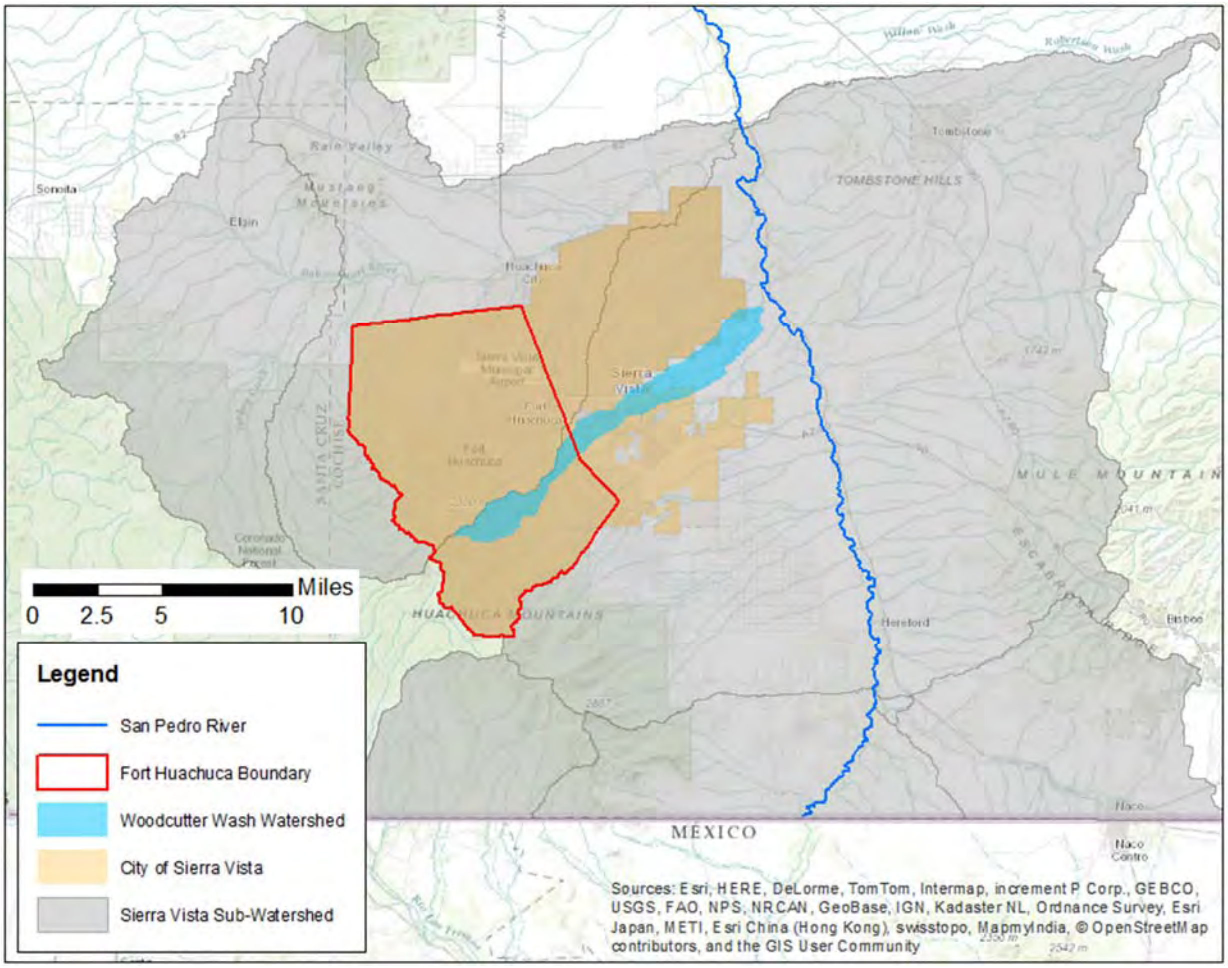

Figure 1. Vicinity Map

Introduction to Low Impact Development

LID is an approach to protect or restore natural hydrological processes throughout new development, re-development projects, or even site retro-fits. By striving to minimize impervious hardscapes, reduce or mitigate soil compaction, preserve natural open space, and utilize constructed features that employ natural living systems, LID works to maintain surface hydrologic systems and ultimately it has the potential to benefit natural systems. Green infrastructure (GI), a suite of practices and structures used in LID, refers to constructed features that use living, natural systems to provide environmental services, such as capturing, cleaning and infiltrating stormwater; creating wildlife habitat; shading and cooling streets and buildings; and calming traffic. Green infrastructure offers an integrated solution to stormwater management, meaning it can provide multiple co-benefits at the same time. GI features manage stormwater as a resource by dispersing it throughout a site or urban area rather than moving it off-site as quickly as possible.

Utilizing a LID/GI approach can have the following:

Benefits

- decreases hardscape extents, which reduces future maintenance costs

- uses self-renewing processes of soil and vegetation that require less maintenance
- decreases compaction to soil surface at time of construction
- restores natural hydrologic processes, which reduces urban enhanced runoff to prevent increases in stormwater volume and peak flow
- provides an irrigation resource for trees and vegetation, which in turn:
    - conserves extractive (i.e. groundwater) water supplies
    - shades & cools communities
    - beautifies neighborhoods
    - provides wildlife habitat
    - increases property values
- potentially mitigates non-point source pollutants in stormwater through filtration and bio-remediation
- integrates with other community goals - such as traffic calming and pedestrian and bicycle safety

Cons

- individual features may not provide large-scale flood control needs
- initial retrofit implementation costs may be high
- requires shifting asset management of stormwater infrastructure to the landscape

Though not an exhaustive list, this section outlines a few of the most important principles that should be followed when using LID practices.

1. Protect and restore natural areas. Natural areas – like forests, grasslands, or relatively undisturbed riparian areas — provide the functions that LID emulates. These areas offer services including air and water filtration, as well as wildlife habitat. When a natural feature like a wetland is removed, it is costly and difficult to rebuild the original feature's complex web of ecological interactions, and thus the services it provides. For this reason it is always preferable to preserve, protect, and buffer natural areas, not only in places that are being newly developed, but also in the pockets of nature that still exist throughout the community. Most remaining undeveloped areas are degraded from their original state. Working with nature to restore these areas' ecological functions and services is an essential practice.

2. Serve multiple functions with LID. LID shifts how we meet community goals. Instead of creating infrastructure that only serves one purpose (like a concrete-lined channel used only to convey stormwater offsite), the best LID practices will serve multiple functions, like calming traffic; improving pedestrian and bicycle pathways; cooling and beautifying streets; reducing and cleaning stormwater runoff; and creating wildlife habitat. Such integrated design creates practices that are more cost-effective and beneficial for communities.

3. Include the community. LID approaches require a multi-disciplinary and inclusive planning and design process. Including local residents, neighborhoods, businesses, and institutions (like schools and churches) is essential to creating projects that are successful and supported over the long term. Engagement through community design charrettes, educational workshops, and tree plantings can be a community-led process that is educational, fun, and builds connections.

4. Require collaborative teams. A LID approach requires collaboration across professional and community sectors from the start. Collaborative team meetings at each design and implementation step will ensure best integration of LID practices. Civil engineers and landscape designers shall identify appropriate LID opportunities and plan in an integrated fashion. At early stages of the design process (e.g. 30% plans) submitted plans should identify proposed LID/GI practices, integrated drainage and landscape areas, and coordinated utility plans. Each successive stage of the design process should include required reviews and reports related to the developing LID plan to ensure an optimal, cost-effective design solution.

Geomorphic Restoration of Channels as an LID practice

Geomorphic channel restoration is an integrated approach to promoting channel health and stability. As urban development increases impervious areas the resulting stormwater runoff is warmer, more polluted, and flowing faster than before. This enhanced urban runoff increases erosion in a channel that no longer has room to meander. While traditional drainage plans focus on hydraulic modification such as hardening banks and installing concrete grade control, geomorphic restoration practices focus on the hydrologic, hydraulic, geomorphic, physicochemical and biological conditions of the channel. Geomorphic restoration practices use natural stream processes to redirect flow, replicate a balanced sediment transport regime and build a stable and resilient channel that is appropriate for the altered urban hydrology.

Similar to LID – geomorphic restoration should achieve multiple benefits (e.g. channel stabilization, wildlife habitat, quality of life aspects) while reducing long-term maintenance and repair costs.

Tackling the Water Deficit

The water withdrawals in the Sierra Vista Sub-watershed currently exceed the rate of recharge by approximately 4,900 acre-feet of water each year.[3] The various demands and supplies to the groundwater aquifer are detailed in Table 1. The proposed LID practices assist in reducing existing and new demands from the City and increase urban development channel recharge to balance the water budget.

LID for Groundwater Demand Reduction

In 2014 the average total water use, including residential, commercial, and industrial uses, of Sierra Vista was 119 gallons per capita per day (GPCD).[4] The residential water use in the Sierra Vista Sub-watershed was estimated at 90 GPCD in 2010.[5] The average total potable water use in Tucson during 2014 was 127 GPCD[6] while the city of Santa Fe, NM achieved 95 GPCD[7]. Given the recent drought, there are some communities in California that have been able to reduce their residential water use to under

[3] http://www.sierravistaaz.gov/water/content.php?fDD=22-247
[4]City of Sierra Vista Department of Public Works 2014 Area Water Use data
[5] Based on a 2010 population weighted average for Sierra Vista and Fort Huachuca compared to other Sierra Vista Subwatershed residents using the 2010 Liberty Water Company's Southern Sunrise residential use of 76 gpcd and an estimated average water use of 112 gpcd for other subwatershed residents. The basis for this estimate being derived from Plateau Resources LLC, 2013, Unmetered Residential and Non-Residential Well Use in the Sierra Vista Subwatershed, Arizona.
[6] http://www.tucsonaz.gov/water/about-us
[7] http://www.santafenm.gov/water_conservation

50 GPCD.[8] LID practices can work to reduce demand for pumped groundwater and continue to lower per capita demand.

Table 1. Sierra Vista Sub-watershed Water Balance (2014)[3]

Sierra Vista Sub-watershed Water Demand	Acre-feet per year	Sierra Vista Sub-watershed Water Supply	Acre-feet per year
Riparian river vegetation	10,800	Mountain front recharge	15,000
Sub-watershed outflow	3,700	Groundwater inflow from Mexico	3,000
Pumped within City of Sierra Vista	5,494	Urban development channel recharge	2,300
Pumped by Fort Huachuca	1,025	City and Fort aquifer recharge	3,000
Pumped by other municipalities and water companies outside of Sierra Vista	3,800	Returned through detention basins	315
Pumped by private wells (assumed)	4,400	Septic tanks and turf watering	2,100
Pumped for industrial uses (golf courses, sand and gravel, etc)	1,500	Mesquite management saves	475
Pumped for irrigation	400	**Total Supply**	**26,190**
Total Demand	**31,119**	**Deficit**	**-4,929**

Groundwater pumped for irrigation can be reduced by installing LID features which harvest rainwater through active and/or passive systems. Active water harvesting practices such as rain barrels and cisterns collect rainwater from rooftops and store it for on-site re-use such as landscaping or indoor uses. The more rainwater that is available for landscaping, the less water is pumped from the aquifer to meet these needs.

Passive water harvesting involves slowing rainwater runoff down and allowing it to soak into the ground. It is an approach to landscaping that retains local runoff and, when combined with native vegetation, creates a sustainable and aesthetic resource for the property owners and community. One of the myths about constructed landscapes in the Southwest is that they always require long-term irrigation. In many cases, the need for long-term irrigation can be eliminated or significantly reduced 1) by using native plants that are adapted to local rainfall patterns, and 2) by placing vegetation in areas where it will receive supplemental rainfall runoff from adjacent rooftops, streets, or parking lots. For example, in Sierra Vista 100 square feet of hardscape or roof produces 800 gallons in an average year. If this runoff is directed to a receiving water harvesting basin planted with 50 square feet of low-water use native plant canopy, the entire water demand of that landscape can be fully met even in a year that receives 75% of average rainfall. A vegetated LID site that does not require long-term irrigation can be achieved if one

[8] http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/rgpcd_2015may.pdf

creates and utilizes a water budget for the site (see The Arizona Cooperative Extension's "Cochise County Rainwater Harvesting Budgeting for Sandy Loam Soils")[9].

Hydrologic modeling that implemented passive harvesting on 10% of parcels indicated that 20.5 acre-feet of water would be collected for on-site uses.[10] While these savings are modest, pairing passive practices with shifting landscaping and maintenance practices would realize actual savings. Using the structures and impervious surface data available from a LiDAR data collection effort, it was estimated that 2,290 acre-feet of water (44% of the deficit) could be harvested if water was collected from all rooftops and impervious surfaces in the City. [11] The majority of this water (1,330 Acre-feet) is coming from the roof surfaces and could be actively collected in both rain tanks and rain gardens. These numbers represent the potential of LID adoption and maximum utilization of runoff throughout the City. The potential water savings from collected rainwater is significant. Additional water efficiency savings (appliances, leak reductions, irrigation controls, etc) by continuing conservation programming are also needed to reduce overall groundwater demand to fully eliminate the water deficit.

LID and Channel Opportunities to Enhance Recharge

Additional investigation of underlying geologic conditions in Sierra Vista is necessary to determine sites favorable for infiltration and groundwater recharge. This report compiles analyses to date to identify and quantify potential enhanced recharge opportunities to increase the supply side of the water budget while enhancing quality of life. From a water budget perspective the return of urban development flow to natural washes for recharge is estimated at 2,300 acre-feet in the Sierra Vista sub-watershed (Table 1). Given that washes in the City makes up approximately 1.7% of the total wash length in the Sierra Vista sub-watershed an estimated average of 39 acre-feet of water is recharged annually within City washes. Enhancing infiltration through channel restoration techniques has the potential to increase aquifer recharge. Augmentation potential from channel enhancements is reviewed later in the report. Additionally, stabilization of these urban washes has the potential to decrease erosion and protect critical infrastructure.

Rethinking Stormwater as a Managed Resource

LID at the parcel and street level

Summary of Benefits

- LID returns $3-$6 for every $1 invested based on report results

Benefits for LID are based on water conservation, air quality improvement, building energy savings, reduced street maintenance, increased property values, avoided grey infrastructure, the social value of water conservation for Sierra Vista, reductions in greenhouse gas emissions, flood risks, groundwater pumping, stormwater pollution, urban heat island and enhanced traffic calming

- LID will not significantly reduce stormwater flow volumes to the San Pedro River

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[9] Contact the program coordinator, Cado Daily (cdaily@ag.arizona.edu), for a copy of the water budget tool.
[10] See the HEC-HMS Results Analysis section in Appendix A for modeling methods and the derivation of this number.
[11] See *Rational Method Assessment of Impervious Surfaces* in Appendix A for details on this calculation.

A hydrologic model that implemented LID on 10% of parcels and streets within the Woodcutter Wash watershed showed that the volume of water reaching the San Pedro River was only reduced by 1% during the 2-year 6-hour storm event.[12]

- LID can significantly help conserve water used in landscapes and even indoor water consumption

A hydrologic model based on the 2-year 6-hour storm event (1.46 in of rainfall) and with a potential LID adoption scenario in the Bella Vista neighborhood (west of 7th St and north of Fry Blvd) collected sufficient water from the one rain event to provide 27 people 140 GPCD for seven days.[13]

- LID can significantly reduce water pollutants through filtering polluted runoff associated with the start of each runoff event

Soil aquifer treatment can mitigate nitrates and bioretention associated with LID features can remove metals and other stormwater pollutants[14,15].

- LID can reduce nuisance flooding impacts from the frequent smaller rainfall events

Peak runoff flow from sub-basins in the hydrologic model of the Woodcutter Wash watershed model were reduced by an average of 3.5% (10% LID adoption) while peak flow coming from the Bella Vista neighborhood west of 7th street were reduced by 12% (max practical LID adoption scenario specifically for the neighborhood).[16]

- Each 100 sq.ft. of impervious area can easily support 50 sq.ft. canopy of native, low-water use vegetation, without supplemental irrigation once established (2-3 years) if passive water harvesting practices are in place.[17] Associated annual water demand reduction for each 50 sq.ft. of canopy would be 250 - 400 gallons (based on a native, low water use tree and common practice of over-irrigating) (Cochise County Rainwater Harvesting Budgeting for Sandy Loam Soils by The Arizona Cooperative Extension and WMG's Water Budget Calculator)

Summary of LID Recommended Actions

- Route stormwater from roofs and hardscapes (asphalt, concrete, etc) to sunken landscape areas before draining offsite. Site grading shall promote water flow to sunken landscaped areas with a maximum retention depth of 8-12 inches in public spaces. Presence of soil limiting percolation conditions may need to reduce the retention depth.

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[12] See Appendix A for further details on the HEC-HMS hydrologic model of the Woodcutter Wash watershed.
[13] See Appendix A for further details on the EPA SWMM hydrologic model of the Bella Vista neighborhood.
[14] Pavao-Zuckerman, M. Soil's Role in Processing Pollutants: Case Studies of Green Infrastructure and Carbon Sequestration. Webinar presented Jan 24, 2013. https://watershedmg.org/video/soils-role-processing-pollutants-air-and-water-webinar
[15] Davis, A.P., Hunt, W.F., Traver, R.G., and M. Clar. Bioretention Technology: Overview of Current Practice and Future Needs. Journal of Environmental Engineering, Vol. 135, No. 3, March 1, 2009.
[16] See Appendix A for further details on hydrologic models.
[17] Contact the program coordinator, Cado Daily (cdaily@ag.arizona.edu), for a copy of Cooperative Extension's water budget tool or Catlow Shipek (catlow@watershedmg.org), for WMG's water budgeting tool.

- Infiltrate collected water in stormwater harvesting basins within 72 hours. This may require shallow basin depths of only 3-4" and compost soil amendments (apply 1-2" of compost across basins) in areas with higher clay content.
- Utilize and maintain understory vegetation, ideally appropriate low-water use native plants, as a functional element of the stormwater harvesting system to ensure pollutant filtration, infiltration, and other community benefits are realized.
- Set requirements of new or redeveloped sites to retain the 15-minute 95% rainfall event on-site (~0.5" for Sierra Vista based on NOAA Atlas 14, vol 1, version 5 accessed 9 July 2013).
- Set requirements of new or redeveloped sites to meet a percentage of on-site irrigation demand utilizing water harvesting practices (see City of Tucson Rainwater Harvesting Commercial Ordinance). Example – New or redevelopment while requiring 25% plant canopy cover shall meet at least 75% of outdoor irrigation demand through water harvesting related practices.
- Set requirements for understory canopy vegetative cover. Understory vegetation, especially native bunch grasses, are critical to ensure soil health and maintain infiltration capacity.
- Reduce roadway width requirements – especially along neighborhood roads – to provide for LID opportunities to treat stormwater and enhance quality of life aspects.

Suggested LID best practices for Sierra Vista

Design hardscape and landscape features to slow flow of water and encourage infiltration of stormwater runoff within the landscape. Additionally, all features will be mindful to

a) provide moisture in the soil for plant materials
b) ensure ease of maintenance, and
c) use and integrate 'waste' materials (e.g. tree trimmings as mulch and salvaged concrete in place of mined rock for rip-rap or screened rock mulch).

Infiltration of retained stormwater runoff is a critical function of green infrastructure. The following considerations are critical to design features that infiltrate retained water within 72 hours:

- Compaction of landscape areas will be avoided. A 12" depth for tilling or ripping will be performed in all plant-able areas which have been compacted.
- On-site soil percolation tests are critical to evaluate the ability of the soil to transmit water through the soil profile.
- Soil amendments and structural soils may be used if necessary to ensure sufficient infiltration of stormwater runoff.
- Areas not ideal for infiltration may need to be supported by rainwater storage tanks for irrigation needs or manage stormwater to meet other objectives.

Plan and implement site grading to promote distribution and infiltration of runoff throughout landscape areas. Concentration of runoff shall be avoided except in the case of directing excess runoff safely into a stormwater conveyance system for downstream benefit. Grading within the landscape areas will ensure the ability to receive runoff, distribute throughout planting area, and promote infiltration through the use of basins, raised berms, and/or checkdams.

Encourage landscape areas over hardscape surfaces wherever feasible. If runoff from adjacent collection areas cannot be directed to the landscape area then the soil surface of the landscape area shall at least be depressed to retain rainfall over the landscape surface for a 0.5" rainfall event (approximately a 1YR, 15min rainfall). Landscape areas shall be designed to collect runoff from surrounding hardscape surfaces. For example, center medians along inverted crowned streets should collect runoff from the adjacent portion of roadway surfaces.

Avoid landscape areas along roadways that are less than 3 feet in width; these areas are infeasible for water harvesting and most planting, and are difficult to maintain. Setback retention areas from roadway edges, sidewalks, utilities, and other critical infrastructure. Specific design standards and setbacks are to be determined per City of Sierra Vista standard details.

Suggested site performance goals may include:

- Retain the 15-minute 95th-percentile rainfall event (~0.5 inches) on-site.
- Meet established (after 3-5 years) landscape irrigation requirements through passive and/or active rainwater collection practices.
- Achieve a tree canopy cover of 25% on-site and utilize landscape trees to shade and cool buildings.

LID makes cents – A costs benefit analysis

LID provides a range of benefits to communities beyond stormwater management. A cost benefit analysis (CBA) was conducted to capture the relevant economic values for LID in the arid southwest. Pima Association of Governments and Pima County's Regional Flood Control District with cooperation from City of Tucson customized the available CBA research for use in the arid southwest.[18] WMG has utilized this research in combination with i-Tree[19] and other research to create a simplified LID CBA tool to quickly assess economic values of LID across the City of Sierra Vista based on basin capacity and number of trees.

The values accounted for in this study are divided into two categories: direct and indirect economic values. Direct economic values have a market value that benefits the property owner, community, or local government such as utility costs or maintenance reductions. Indirect economic values are not currently reflected by local or regional markets but can be estimated through related costs to society. For example, extreme temperatures as a result of the urban heat island effect results in medical costs that are borne typically by elderly populations. By reducing the risk of stress through LID, it is possible to reduce the occurrence of heat stress related costs. A breakdown of the direct and indirect economic values that are included in the CBA are listed below.

Direct economic values:

- Water conservation
- Air quality improvement
- Energy savings
- Reduced street maintenance
- Stormwater runoff reduction
- Property value increases
- Avoided grey infrastructure

Indirect economic values:

- Social value of water conservation
- Greenhouse gas emissions reductions
- Flood risk reduction
- Energy for groundwater pumping
- Stormwater pollution reduction
- Urban heat island reduction
- Traffic calming

[18] Impact Infrastructure, Stantec, 2014. Evaluation of GSI/LID Benefits in the Pima County Environment.
[19] I-Tree Streets. https://www.i-Treetools.org/

The graphs and charts below show the return on investment for rain gardens as well as a breakdown of the categories of benefits associated with rain gardens. These figures represent a 75 square foot rain garden.

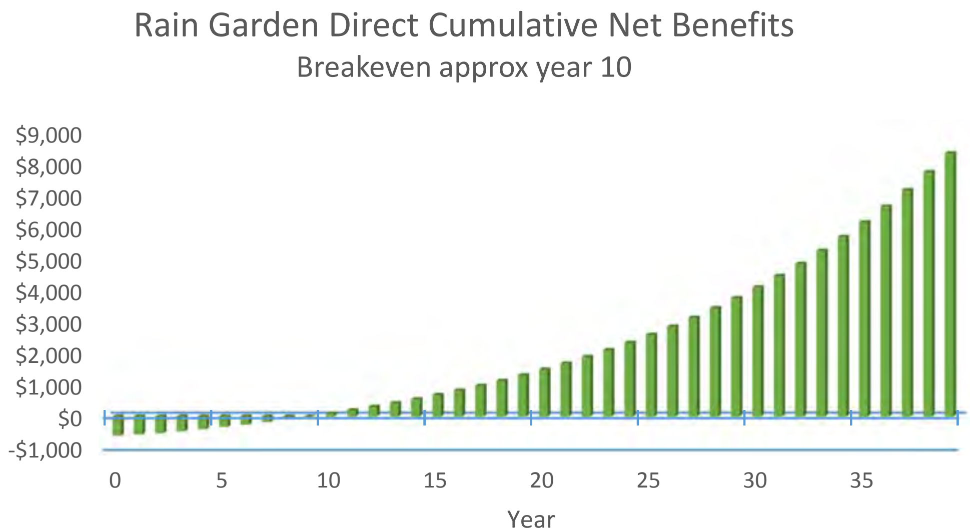

Figure 2. Sum of annual costs and direct benefits

Figure 2 shows the sum of capital costs, annual maintenance and annual benefits. The results are cumulative by carrying over any balance from the previous year. Rain gardens break even at approximately year 10 for direct net benefits. At an inflation rate of 6.5% the net present value (NPV) of the rain garden is $1,280 over the 40 life of the infrastructure. This creates a NPV Benefit/Cost ratio of $2.60 for direct benefits.

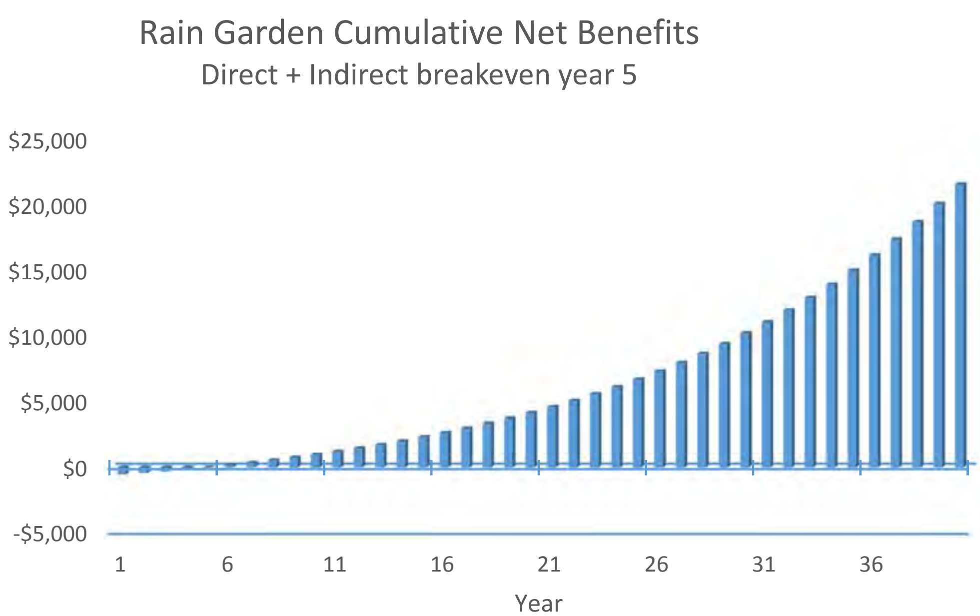

Figure 3. Sum of annual costs and direct + indirect benefits

Figure 3 represents the sum of capital, annual maintenance and annual benefits. When including direct and indirect benefits, rain gardens result in a 5 year breakeven period. This creates a NPV Benefit/Cost ratio of approximately $6.00 and a total NPV of $4,880 over the 40 life of the infrastructure.

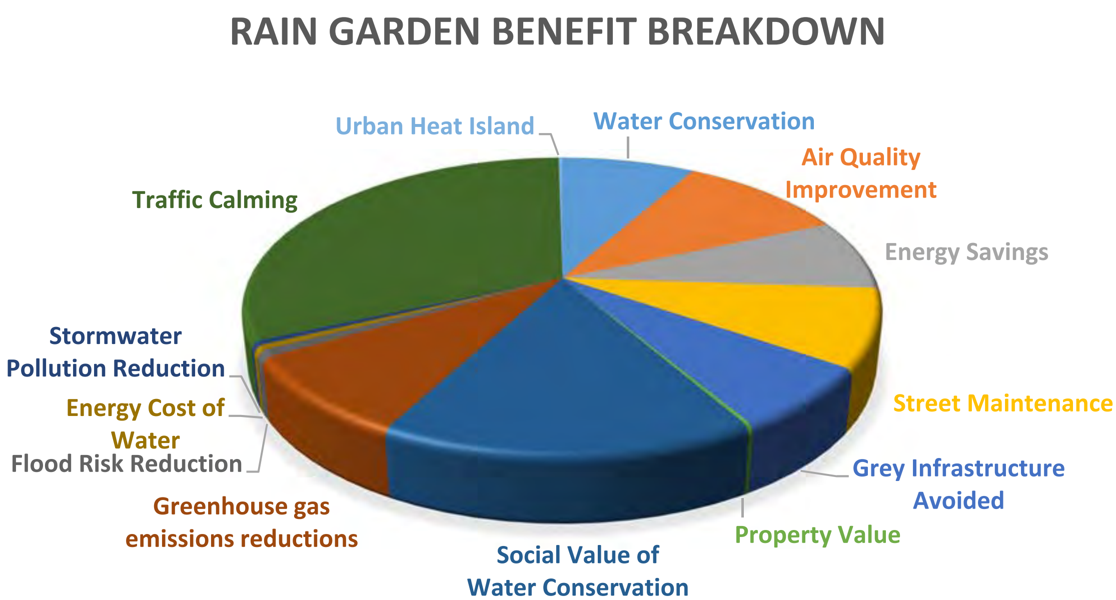

Figure 4. Breakdown of relative rain garden benefits

The primary direct financial benefits from rain gardens result from water conservation, air quality improvement, building energy savings, avoided street maintenance and grey infrastructure. The total value created by the 75 sq.ft. rain garden in Figure 4 is approximately $115 in annual benefits.

Watershed Scale Results

Costs and benefits were assessed for a scenario assuming 10% of the City of Sierra Vista adopted LID practices. This could likely occur over a 10-20 year timeframe depending on the incentives and economic development. Implementation of this 10% scenario would realize $145 million in benefits. Project costs would be minimized if integrated into redevelopment and other capital improvement projects. LID retrofit features that involved removing asphalt and concrete were excluded from the above results. The high cost associated with hardscape removal outweigh any benefit created by LID features. These features make economic sense during redevelopment when hardscape surfaces need to be removed as a part of construction. It will be important to incentivize cost effective LID practices and the results of the cost benefits analysis can be utilized to appropriately design and implement an effective incentive program to match the costs and benefits with the entities who receive the benefits.

There are other benefits created by LID such as habitat creation. However, additional research is needed before financial values can be utilized in cost benefit analyses with confidence. All NPVs used a discount rate of 6.5% over 40 years to accurately reflect the long-term benefits of LID and to be consistent with the 'Evaluation of GI/LID Benefits in the Pima County Environment' report[20] and other infrastructure cost benefit analyses.

LID vs. Grey Infrastructure

LID practices have many benefits over grey infrastructure alternatives. Grey infrastructure often is referred to as hard or traditional infrastructure features that do not utilize natural systems and have a single purpose. Although stormwater management and flood mitigation challenges in many cases in the southwest will not be solved with LID alone, grey infrastructure use can be reduced and/or resized to save costs and create additional community benefits when used in combination with LID.

Larger flood control projects such as detention basins will always have a low cost per gallon of flood water mitigated relative to LID features because they serve a sole purpose. When the multiple benefits of LID are incorporated, the financial benefits of LID outweigh the benefits of detention structures. An equivalent area (1/2 acre) of rain gardens and detention basins were compared. Although the detention facility had 5 times the flood mitigation capacity, the LID features had a greater Benefit/Cost ratio.

	Capital Cost	Annual Maintenance	NPV	B/C Ratio
Rain Garden	$280,000	$7,000	$1,900,000	$4.99/$1
Detention Basin	$245,000	$12,000	-$665,000	$0.01/$1

Conventional landscape areas for parking lots and street sides were compared with LID parking lots and LID Green Street areas. The table below is based on a 1,300 square foot comparison for a xeriscape landscape without water harvesting features that was assumed to represent a conventional landscape.

	Capital Cost	Annual Maintenance	NPV	B/C Ratio
LID Street/Parking lot Landscape area	$14,000	$112	$58,000	$4.73/$1
Conventional Street/Parking lot	$6,900	$155	-$7,500	$0.40/$1

Residential landscapes of 200 square feet were compared to better understand the short and long-term costs and benefits of conventional practices relative to LID based landscapes such as rain gardens.

	Capital Cost	Annual Maintenance	NPV	B/C Ratio
Rain Garden	$1,300	$32	$4,600	$3.05/$1
Turf Yard	$289	$205	-$6,600	$0.50/$1
Xeriscape	$1,000	$23	-$1,500	$1.55/$1

[20] Impact Infrastructure, Stantec, 2014. Evaluation of GSI/LID Benefits in the Pima County Environment.

Instituting LID - Policy Opportunities

Current implementation of LID features is voluntary. The City of Sierra Vista has actively promoted LID features for new and redevelopment projects. In the last few years, although development has been limited, the few sites that have been developed have adopted some form of LID, primarily rainwater tanks and/or landscaped rain gardens. However, to achieve greater adoption rates and ensure meaningful LID practices are implemented an investigation of policy opportunities was conducted.

A review of the City of Sierra Vista's Development Code highlighted several opportunities to better promote adoption of LID features and reduce barriers to effective LID implementation. The majority of the suggested changes are contained in the listed points made in "Summary of LID Recommended Actions" under the "LID at the Parcel and Street Level" section. A detailed summary of suggested changes listed by code section is provided in Appendix D. Detailed edits to the current development code for each section can be provided upon request.

Ultimately, funding incentive programs or retrofits is an up-front cost that results in a positive return on investment over the feature's lifetime. LID also requires a shift in costs from hard (i.e. concrete) infrastructure maintenance to soft (i.e. landscape) infrastructure. To help with these short-term and up-front funding shortfalls it is advised to set up specific funding mechanisms for the adoption of LID throughout the community to achieve desired goals.

Potential funding for LID may be generated through:

A) Developing a water offset program where a developer implements groundwater reduction practices or pays a fee in lieu of implementing to offset the impacts of the proposed project. This may provide funding for LID or other water conserving features that can realize a groundwater savings.

B) A stormwater investment fee or other fee that generates revenue to promote, implement, and maintain LID features. For example a $2/month fee assessed to city parcels could generate ~$290,000 per year. Rates could vary by zoning classification, impervious area, and/or if the site has implemented LID or not.

C) Other roadway fees, waste hauling fees, or fuel tax options could be explored to ensure a longer-term revenue generating stream for LID adoption to achieve desired community stormwater, vegetation, and groundwater reduction goals.

Looking Downstream of LID

LID benefits downstream opportunities

LID in upland areas can help set the stage for increasing the opportunity to improve conditions in washes. Hydrologic model results were used to calculate velocity reductions during the 2-year 6-hour storm event. Reduced flow volumes result in diminished velocities and shear stresses which will entrain less sediment. Velocity reductions ranged from 4.3% to 26% of the existing condition velocity. Where concentrated stormflow enters natural channels the reduced flow velocity diminishes local erosion of the bed and banks. Reductions in channel bed and bank erosion may also be realized along channels. Further, retention of stormwater in upland sites can also benefit channels by:

- Reducing pollutant loads reaching the channels through both volume abstraction and bio-remediation processes of vegetated rain gardens
- Lessening the need for impervious, concrete conveyance channels
- Diminishing the need for channel armoring and maintenance due to establishment of protective vegetative cover along banks.
- Creating linkage corridors between wildlife habitat in washes and developed areas

Urban Channel Enhancements

Summary of Benefits

- Vegetated wash corridors benefit wildlife by providing travel ways, cover, and food[21]
- Improvement of water quality through additional bio-filtration and reduced sediment loads
- Enhancement of channel bed recharge to aquifer
- Reduced erosive potential and risk of critical banks
- Increased wetting of bed and banks to promote protective vegetative cover and enhancement of local aquifer recharge
- Re-establish floodplain connections to dissipate flood energy, filter pollutants, and further enhance recharge
- Promote re-establishment of xeroriparian forest to improve local air quality, cooling, and aesthetics

Summary of Recommendations

- Recognize that washes and streams are common corridors for wildlife and that management of channels should preserve and enhance native plant habitat
- Adopt a geomorphic channel design approach to stabilize channels
- Design and implement grade control structure drops based on the natural grade of channels and in where practical limit vertical drops to a maximum of three vertical feet per structure
- Mimic channel morphology of stable channels when restoring degraded channels
- Identify, assess, and implement a pilot channel reach to serve as a demonstration of geomorphic channel restoration to evaluate performance related to bed and bank stability, enhancement of channel bed recharge, and vegetative cover

Suggested Channel Best Practices for Sierra Vista

- Where feasible, the geomorphic-based design approach to channel stabilization should be used. It can provide multiple community benefits including groundwater recharge, wildlife habitat enhancement/creation, and achieves quality of life objectives outlined in the Sierra Vista General Plan.
- Identify areas with greater permeability to locate geomorphic-based features to stabilize channel bed grades and slow flows to promote enhanced recharge and vegetative establishment.
- Use features that promote streambed infiltration and bank storage wherever possible.
- Use local rock and aggregate material, if suitable.

[21] Stantec, KBR, and Watearth, 2013. Evaluation of Natural Channel Design versus Traditional Stormwater Infrastructure in Texas. Texas Water Development Board.

- Mimic channel bed slopes of the existing grade of stable local streams, particularly at culvert crossings, so that sediment/bed loads are maintained and excessive erosion or deposition is avoided.
- All grade-control structures shall promote incidental recharge in natural channels, if local geological conditions suggest favorable infiltration rates and subsurface flow. A geological report that evaluates the recharge potential of the location shall be completed by an Arizona-registered geologist or civil engineer and become part of the design documents for the grade-control structure.
- Mimic the fluvial structure of stable reaches of existing washes wherever possible. Acceptable methods of natural erosion control can be obtained from the National Engineering Handbook, Part 654, NRCS Stream Restoration Design, US Department of Agriculture, National Resources Conservation Service.

A literature review of hydrogeological conditions in the City was performed by Hassayampa and is included in Appendix B. The findings of this report indicate that field measurements are needed in locations where enhanced recharge is proposed in order to determine if there is a limiting calcic layer or fine-grained unit that would prevent deep percolation. The City estimates of hydraulic conductivity based on NRCS soils data provide the best estimate for surface infiltration. Stretches of wash in Sierra Vista are shown in Figure 5 along with the estimated hydraulic conductivity of the underlying soils. The northernmost and southernmost washes have the highest hydraulic conductivity but the shortest lengths of wash within the City.

There are 23 miles of wash that run through the developed area of the City. This is estimated to be 1.7% of the total wash length in the Sierra Vista Sub-watershed. Natural channel recharge in the Sierra Vista Sub-watershed is estimated at 2,300 acre-feet annually. Therefore, a rough estimate of annual recharge within the washes of the City is 39.1 acre-feet. Assuming that every mile of wash in the City could be enhanced to increase hydraulic conductivity by 0.45 inches/hr[22], then 43.93 acre-feet of water (minus evapotranspiration losses) would be recharged annually, in addition to the current annual recharge of 39.1 acre-feet. Given that an increase in infiltration is not possible in every mile of stream running through the City, a more probable estimate of enhanced recharge was performed. Assuming that channel improvements could increase channel infiltration by an average of 0.45 in/hr, improvements to 25% of the grade control structures in the City (18 structures) would result in 2 acre-feet of additional recharge. This estimate assumes that grade control structure improvements will enhance recharge in at least 300 linear feet of channel associated with each channel feature.

Geomorphic channel restoration analyzed as an enhanced supply viewpoint is cost prohibitive. However, if tied to infrastructure protection, flood mitigation, and urban forestry for quality of life values, it can be a realistic approach. Geomorphic channel restoration can be an alternative to traditional concrete or

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[22] Field and laboratory measurements of hydraulic conductivity at sites in the 3rd Street Wash watershed were up to 0.45 in/hr more than the estimated hydraulic conductivity of 0.4 in/hr. Sites in the Coyote Wash watershed were higher (6.6in/hr) even though the estimated hydraulic conductivity underlying Coyote Wash is lower. See May 2015 technical memorandum *Opportunities for recharge using grade-control structures* by Hassayampa Associates.

gabion grade control features and tied to annual capital spending required to install, maintain, or replace aging structures.

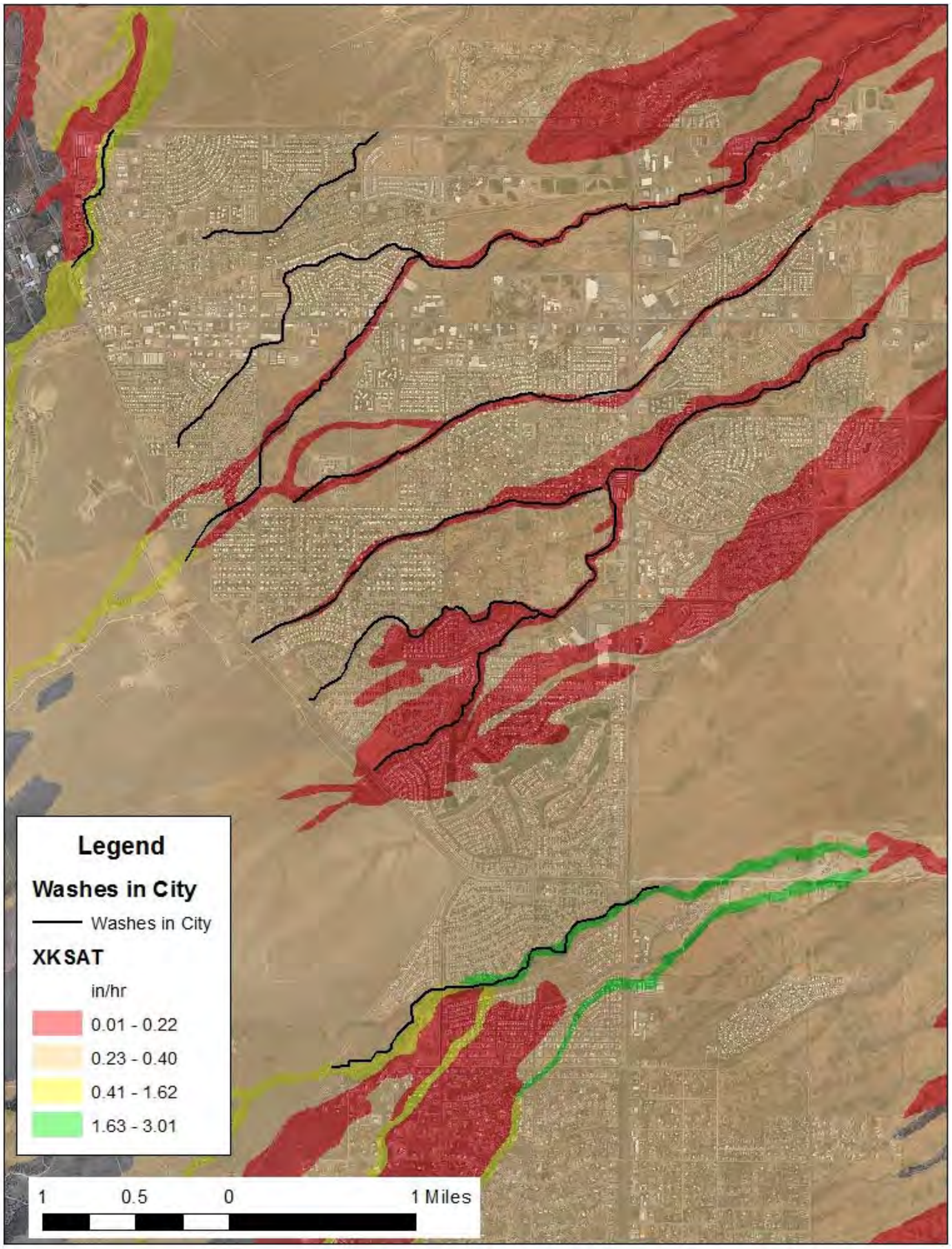

Figure 5. Hydraulic Conductivity (XKSAT reported in in/hr) of soils under City washes

Brainstorming an Integrated Stormwater Management Approach

How do we start and where do we start? How can this be funded? Shifting an approach at a community scale can be overwhelming. Thankfully, Sierra Vista and the greater community has taken great strides forward in regards to demonstrating benefits derived from LID practices. We can apply lessons learned from geomorphic-based channel restoration practitioners based in New Mexico who have implemented both urban and rural demonstrations.

To further progress made along this new path WMG engaged a diverse group of local stakeholders (including City and County staff, development interests, BLM, The Nature Conservancy, Cochise Water Project, Cochise County Smartscape, and others) through a focus-group session in September 2015. Ideas proposed in this session included traditional approaches to LID as highlighted previously, but also included integrated stormwater management features that blended on-site LID with channel-based projects to develop new sources of water for community benefits while balancing short-term downstream recharge opportunities with a longer-term focus on diminishing the underlying cone of depression.

Conversation quickly focused on the need to develop a watershed-based plan that integrated stormwater management while establishing assessment criteria to determine optimal use of site generated stormwater based on balancing site and community needs with environmental constraints. Discussion was focused on how do we prioritize and fund needed infrastructure, outreach, and analysis. The following sections addresses what is needed to achieve the desired objective of ending the sub-watershed groundwater deficit and begin to restore the aquifer to ensure long-term health of the San Pedro River and support economic growth.

Linking Site Health to Community Health to San Pedro River Health

A simple water-balance model was developed to better understand the level of effort required to end the groundwater deficit and restore aquifer health. The model includes demands and supply for the entire Sierra Vista sub-watershed portion of the San Pedro River. However, our analysis evaluated primarily the parameters the City had within its control. Outside of the city's jurisdiction the analysis maintained current trends (e.g. water conservation). Ultimately, neighboring communities and the County will need to be included to provide a shared effort to improve watershed health. Appendix E contains the details of the water-balance model stated assumptions and scenario parameters.

The current estimated deficit for the sub-watershed is 5,270 acre-feet per year with a total cumulative deficit greater than 800,000 acre-feet. The cumulative deficit will continue to grow each year there is an annual deficit. Our analysis indicates that by focusing on a suite of conservation activities (e.g. indoor efficiencies, rainwater and stormwater utilization through LID, etc.) to reduce groundwater demand the deficit can be eliminated. By enhancing the incidental recharge of 10% of the streams through geomorphic channel restoration where suitable, or other stormwater infiltration practices the supply available to recharge the aquifer can increase.

Based on the scenario outlined in Table 2, the annual groundwater deficit would diminish over a 12 year period and end in 2027 (see Figure 6). Supply enhancement through channel treatments within the City increased by 25 acre-feet. The impact of groundwater demand reduction through a suite of conservation efforts can have the greatest impact to achieve an annual water balance. Expanding targeted conservation and channel enhancement treatments throughout the sub-watershed could realize an annual balance (net-zero) in a shorter period of time.

Table 2. Sierra Vista Sub-watershed Water Balance Model Scenario Parameters

Scenario Timeframes	Portion of Current Water Supply Available (assumed)	Sierra Vista Population Growth Rate per year (assumed)	Other Community Population Growth Rate per year (assumed)	Sierra Vista per Capita Demand Reduction per Year (assumed)	Other Community per Capita Demand Reduction per Year (assumed)	Portion of Sierra Vista Channels Treated to Enhance Recharge (assumed)
2015-2020	100%	0.0%	2.0%	-6.0%	-4.0%	5.0%
2021-2025	100%	1.0%	2.0%	-4.0%	-2.0%	5.0%
2026-2030	98%	1.0%	1.0%	-4.0%	-2.0%	5.0%
2030-2050	97%	1.0%	1.0%	-1.0%	-1.0%	5.0%
2050-2100	96%	1.0%	1.0%	-.05%	-.05%	0.0%

Ultimately, the goal for the Sierra Vista sub-watershed is to achieve a net-positive water balance to reverse the cumulative impact of groundwater withdrawals over the past decades and begin aquifer recovery (see Figure 7). This will require continued conservation and innovation as the population continues to grow in the region.

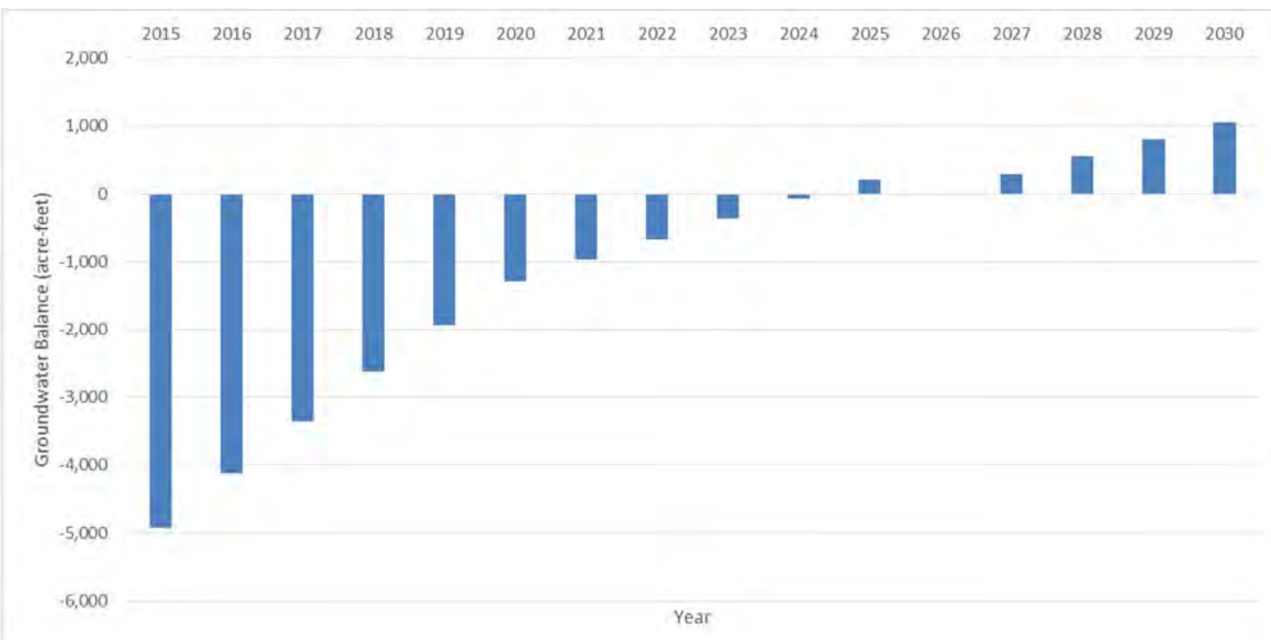

Figure 6. Sierra Vista Sub-watershed Annual Water Balance (2015 – 2030)

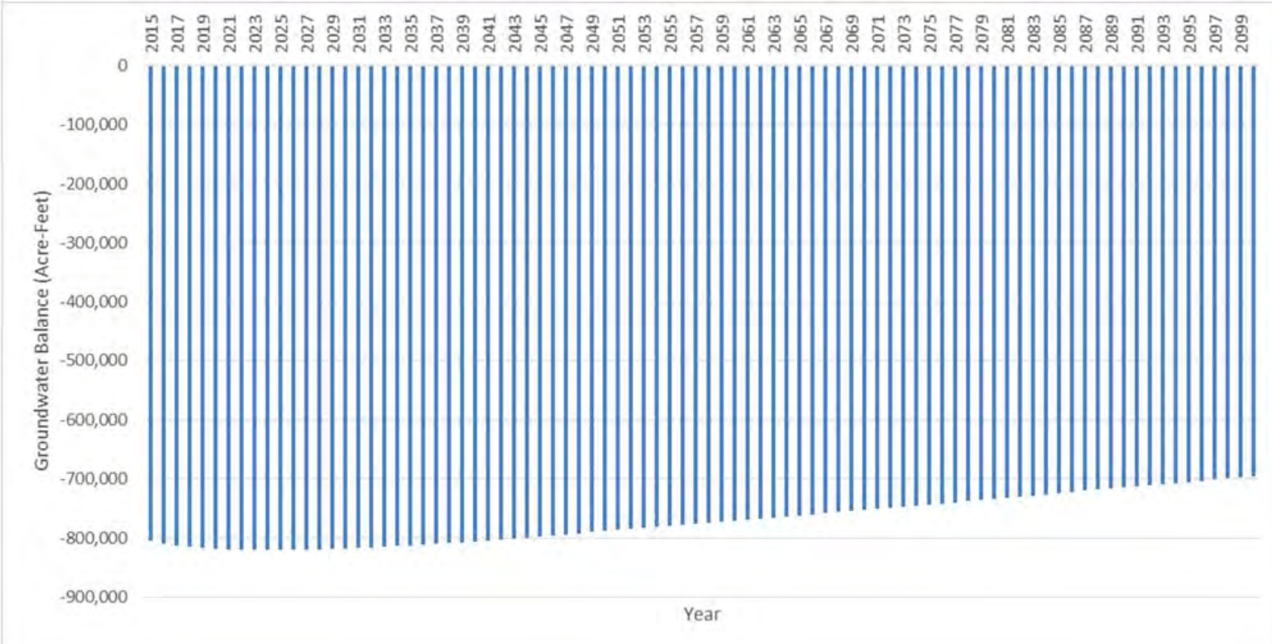

Figure 7. Sierra Vista Sub-watershed Cumulative Groundwater Total Deficit (2015 – 2100)

Next steps

Through our collaborative work with the City and partners we have identified a flexible approach to meeting community needs and ensuring economic growth while achieving a net-positive water balance to restore the aquifer and sustain the health of the San Pedro River. Moving forward it is imperative that we all work to increase collaborative partnerships among diverse stakeholders that are solution focused (e.g. the emerging Cochise Conservation Recharge Network). The next three sections list suggestions to explore further. These include a) site-based improvements, b) watershed-based planning for integrated management of stormwater, and c) development of sustainable financing for action items.

LID Improvement Projects

- Identify specific community problems (e.g. nuisance flooding, traffic calming, erosion, aesthetics, etc) and choose LID features that can address or mitigate while achieving water supply/demand objectives.
- Create checklists for Public Works and Parks departments to aid in the review of maintenance or capital projects associated with roads, stormwater infrastructure, community facilities, etc where low cost stormwater enhancements could be performed to serve water supply/demand needs.
- Target parks, golf courses, schools, sporting fields, and other high landscape water uses to minimize extent of turf and incorporate rainwater or stormwater reuse for irrigation needs. A great example of this is the Kino Environmental Restoration Project facility in Tucson, AZ. Stormwater retention basins collect and store an average of 55 acre-feet per year[23] of urban

[23] KERP harvested stormwater for irrigation, http://www.kinosportscomplex.com/kerp.shtml

stormwater runoff for ballpark re-use while providing additional benefits for wildlife, open space, etc.

- Explore a range of larger stormwater enhancement projects to provide an aquifer recharge and/or a re-use benefit. Below is a summary of potential projects which are highlighted on the map in Figure 8:
  - Enhance degraded channel systems to provide a floodplain connection and/or grade control through geomorphic restoration practices. This can increase channel recharge, protect critical road and utility infrastructure, and provide a vegetation component for wildlife and/or quality of life values.
  - Retrofit commercial centers (e.g. Fry Blvd & 90, Sierra Vista Mall and adjacent commercial centers) to provide significant water resources for demand reduction (e.g. on-site or off-site irrigation) or be directed to recharge facilities downstream.
  - Develop a KERP-style facility (i.e. along the arroyo between Veteran's Memorial Park and the sports field complex) to provide an irrigation benefit and perhaps an increase in aquifer recharge.

Watershed Planning for Developing an Integrated Stormwater Management Approach

- Assess recharge rates within washes when planning channel restoration or grade control projects.
- Identify and map geologic lineaments to prioritize areas that may be conducive to enhance recharge.
- Create a stormwater management decision making matrix for site development based on site use, context, and geologic constraints to prioritize allocation of stormwater resources for supply, demand reduction, or other community quality of life objectives.
- Continue review of development code and other regulations and incentives to further influence and foster appropriate development/redevelopment.
- Expand public education initiatives to expand stewardship across a greater portion of sites by demonstrating LID benefits and the payback of initial costs. It is necessary to combat the idea that requiring integrated stormwater management in new development or redevelopment will be too costly.

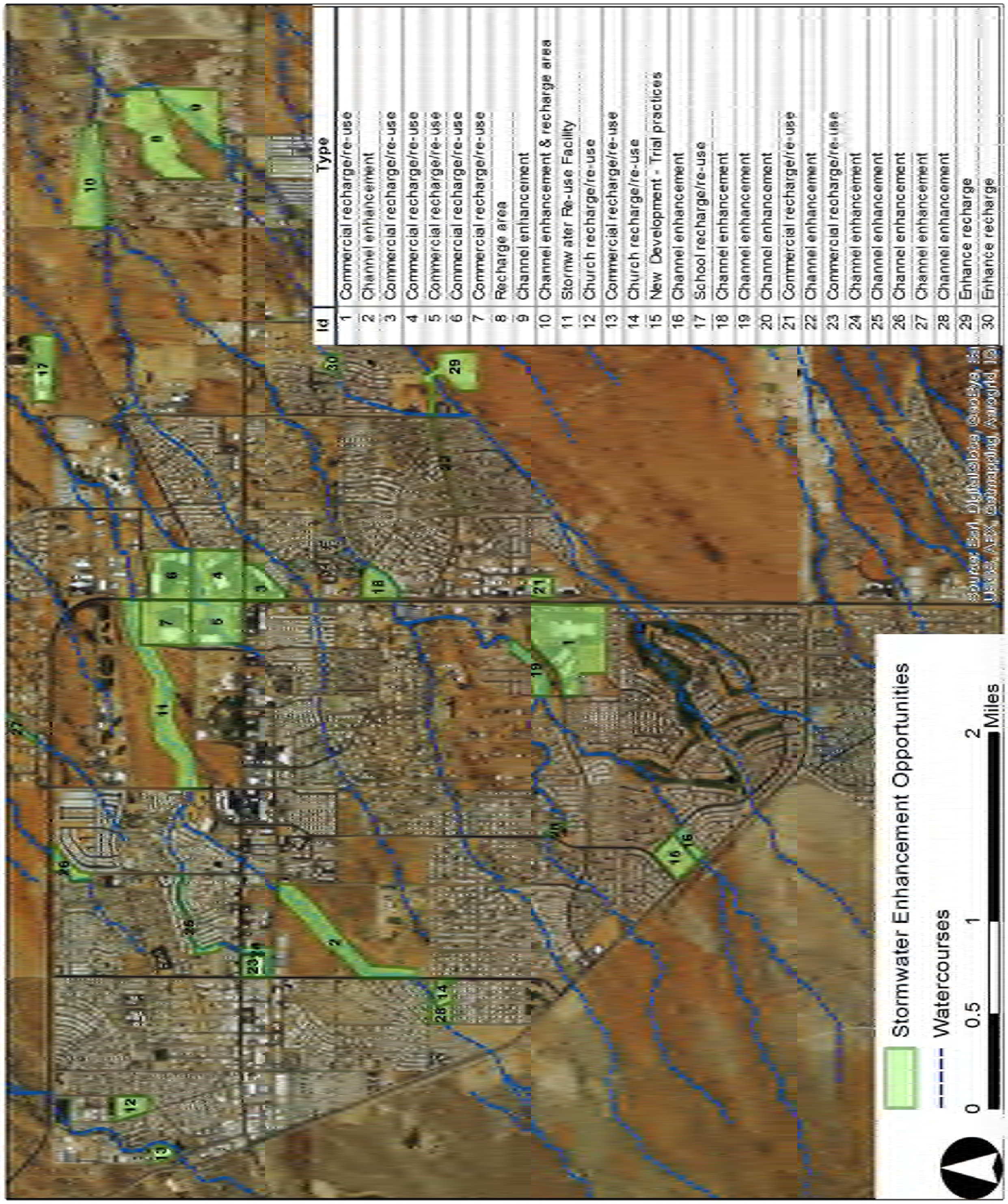

Figure 8. Potential opportunities for stormwater enhancements to provide either water resource supplies or to recharge the aquifer or both.

Establish Financing and Incentives

- Create a local funding mechanism for stormwater infrastructure that enhances or conserves groundwater supplies.
- Set requirements for net positive developments where the development will enhance local water supplies and watershed health rather than only extract groundwater.
    - Explore and develop a water offset program where a water augmentation ratio of greater than 1 is set to ensure a positive trend in water supply.
    - Utilize site runoff for enhanced recharge projects to increase positive supply to the aquifer where site conditions allow.
- Design landscaping ordinances/policies that ensure functional landscapes from an integrated stormwater perspective and meet performance-based metrics at time of installation and years later.
    - Phase in commercial landscaping restrictions with the goal to support all landscapes 100% by rainwater harvesting except during drought years. During drought years, defined by 75% of average rainfall, landscaped areas will be at least 50% supported by rainwater harvesting.
    - Develop a water conservation fund administered locally. The fee could be generated through a groundwater pump fee of non-exempt well users or through a parcel/user fee based on type/class of water use. The fee can be proportional or directly related to water consumption.
    - Phase in residential landscape water restrictions in coordination with landscape/water harvesting incentive program(s).
- Create a central database to track location and characteristics of LID features implemented within the City. Use this to update the Surface Water Plan, ensure coordination with the Conservation and Recharge Network, and identify when a tipping point is reached with regards to conservation, stormwater capture, or other set targets.

Final Remarks

Tremendous effort has enabled Sierra Vista and the greater sub-watershed to reverse the accelerated growth of groundwater demand. The low hanging fruit for water conservation and enhanced supply has been plucked. There is not a silver bullet for moving forward. However, through adoption of an expanded water resource portfolio that includes rainwater and stormwater, Sierra Vista can demonstrate to the Southwest how watershed health can drive economic growth.

The integration of stormwater management from the parcel to the sub-watershed can be mutually beneficial for balancing short-term base flow in the San Pedro with longer-term aquifer recovery as realized from this study. In addition a significant return on investment can be realized for LID projects that achieve multiple community benefits. Through continued creative and pragmatic innovation Sierra Vista is on the cusp of ensuring a future that equally promotes environmental, social, and economic prosperity.