Implementation of the Upper San Antonio River Watershed Protection Plan by incorporating and building upon stakeholder input to develop common goals and investment priorities for implementing green stormwater infrastructure (GSI).

GSI Master Plan

Subtask 5.2 - Upper San Antonio River Watershed Protection Plan Implementation

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PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

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List of Acronyms

BASINS	BETTER ASSESSMENT SCIENCE INTEGRATING POINT AND NON-POINT SOURCES
BMP	BEST MANAGEMENT PRACTICE
CAR	CORRECTIVE ACTION REPORT
CAP	CORRECTIVE ACTION PLAN
COC	CHAIN OF CUSTODY
CRP	CLEAN RIVERS PROGRAM
CWA	CLEAN WATER ACT
DEM	DIGITAL ELEVATION MODEL
EPA	ENVIRONMENTAL PROTECTION AGENCY
EWRE	ENVIRONMENTAL AND WATER RESOURCES ENGINEERING
S DRIVE	SAN ANTONIO RIVER AUTHORITY'S INTERNAL GENERAL PROJECT DRIVE/FILE SERVER
GIS	GEOGRAPHIC INFORMATION SYSTEM
GIS LIBRARY	GEOGRAPHIC INFORMATION SYSTEMS LIBRARY OF SHAPEFILE DATA
GSI	GREEN STORMWATER INFRASTRUCTURE
GSSHA	GRIDDED SURFACE/SUBSURFACE HYDROLOGIC ANALYSIS
HSG	HYDROLOGIC SOIL GROUP
HSPF	HYDROLOGIC SIMULATION PROGRAM – FORTRAN
IC	IMPERVIOUS COVER
LAN, INC.	LOCKWOOD, ANDREWS, AND NEWNAM, INC.
LRT	THE LOAD REDUCTION TOOL
LULC	LAND USE AND LAND USE
NPS	NONPOINT SOURCE
NRCS	NATURAL RESOURCES CONSERVATION SERVICE
PM	PROJECT MANAGER
QA	QUALITY ASSURANCE
QAO	QUALITY ASSURANCE OFFICER
QAPP	QUALITY ASSURANCE PROJECT PLAN
QAS	QUALITY ASSURANCE SPECIALIST
QMP	QUALITY MANAGEMENT PLAN
QPR	QUALITY PROGRESS REPORT
SARA	SAN ANTONIO RIVER AUTHORITY
SOP	STANDARD OPERATING PROCEDURE
SROI	SUSTAINABLE RETURN ON INVESTMENT
SWQM	SURFACE WATER QUALITY MONITORING
TBL	TRIPLE BOTTOM LINE
TBL-CBA	TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS
TCEQ	TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
TNRIS	TEXAS NATURAL RESOURCES INFORMATION SYSTEM
TUT	TIME SERIES UTILITY TOOL
USEPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
USGS	UNITED STATES GEOLOGICAL SURVEY
WPP	WATERSHED PROTECTION PLAN
WQV	WATER QUALITY VOLUME

Subtask 5.2: Draft GSI Master Plan

The Green Stormwater Infrastructure (GSI) Master Plan - Upper San Antonio River (USAR) Watershed Protection Plan Implementation (WPPI) involved developing a master plan for the use of GSI to manage stormwater quality within the watershed. This plan was funded in part by the U.S. Environmental Protection Agency (EPA) 319(h) Clean Water Act Grant through the Texas Commission on Environmental Quality (TCEQ), and the San Antonio River Authority (River Authority). A Hydrological Simulation Program – Fortran (HSPF) modeling effort was conducted to support GSI planning and performance evaluation. The plan incorporates and builds upon stakeholder input to develop common goals and investment priorities for implementing GSI. This project will help guide decision-makers on where and how to apply limited resources in the upcoming years to maximize water quality benefits. It also integrates water quality with water quantity concerns, providing recommendations on best management practices (BMP) that can achieve both water quality and quantity goals.

The River Authority's watershed scale models have identified sub-basin areas with the highest potential pollutant loads. This project uses existing data and modeling tools to identify and prioritize sites within those areas that have the highest potential for GSI implementation effectiveness due to:

- The likelihood of the GSI site being a significant source of nonpoint source pollutants according to water quality data and geospatial data on soils, land use, etc.
- The suitability of each site for GSI implementation according to geospatial data on existing stormwater infrastructure, topography, impervious cover, etc.
- The availability of each site for GSI implementation; promising categories include public lands, capital improvement projects, city planning areas, and neighborhoods with supportive stakeholders such as homeowners' association partners.

The River Authority scored, and prioritized potential projects based on costs, water quality and other benefits, site restrictions, and stakeholder input. Lockwood, Andrews & Newman (LAN) supported the effort by developing a BMP Ranking matrix to help with scoring potential GSI sites. For the recommended sites, the San Antonio River Authority developed site-scale models, concept-level designs, and cost estimates. An existing sub-basin level HSPF model was revised to allow site-scale modeling of each GSI site and to support GSI performance evaluation. Using the modeling results, the River Authority estimated the pollutant load reductions these GSI projects would achieve across the watershed. In coordination with watershed stakeholders, the River Authority developed a GSI Master Plan that included a recommended schedule of implementation, address the stakeholder process, costs, funding considerations, and overall evaluation and prioritization process.

The GSI Master Plan also includes an evaluation of triple bottom line (TBL) benefits and sustainable return on investment (SROI). TBL evaluation monetizes the benefits and costs of activities in the three functional areas: social, environmental, economic. The TBL framework (Subtask 5.1, p.102) has been implemented by governments, policy makers, and economic development practitioners seeking to incorporate social and environmental benefits along with economic benefits into decision-making.

The approach developed in this GSI Master Plan can become a template for future implementation in other watersheds in the area and throughout the country.

The GSI Master Plan is based on the analysis of existing data and additional site-specific modeling to identify areas of significant loading and transport of nonpoint source pollutants, GSI opportunities (HSPF Modeling for BMP Performance Evaluation), costs of those opportunities, GSI prioritization (Subtask 3.2: GSI Prioritization and Cost Report), TBL and SROI report findings (Subtask 5.1: TBL and SROI Evaluation Report), and the stakeholder report (Subtask 4.3: Stakeholder Engagement Report). Task 3 deliverables (Documentation of Subcontracts, Dataset of Potential GSI Projects, Modeling Documentation, and GSI Prioritization and Cost Report) are added as appendices.

HSPF Modeling for BMP Performance Evaluation

A. Introduction

A Best Management Practice (BMP) performance evaluation HSPF modeling was conducted under the Upper San Antonio River (USAR) Watershed Protection Plan Implementation – Green Stormwater Infrastructure Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP; SARA, 2020). This project was sponsored by the Texas Commission on Environmental Quality (TCEQ) and the San Antonio River Authority (RIVER AUTHORITY), and the HSPF modeling effort was conducted by Lockwood, Andrews & Newnam, Inc.

The effort involved developing conceptual green stormwater infrastructure (GSI) designs at eight selected subbasins within the USAR Watershed with one GSI site per subbasin. The previously developed and calibrated subbasin-scale HSPF model was refined to perform site-scale water quality (WQ) modeling at each of these eight GSI sites to evaluate BMP performance. The HSPF model was set up to simulate *E. coli* (EC) bacteria, water temperature, dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD), nitrate nitrogen, ammonia nitrogen, organic nitrogen, total phosphorus, orthophosphorus, and total suspended solids (TSS). The target constituent and the focus of the modeling effort is EC.

One of the eight GSI sites was selected for HSPF model calibration. The calibration involved comparing the HSPF results against those obtained from the corresponding two-dimensional (2D) Gridded Surface Subsurface Hydrologic Analysis (GSSHA) modeling using the same site, as well as the modeling of the BMP using the SARA Enhanced BMP Tool. Details of the calibration are documented in Attachment A entitled “Calibration of Site-Scale HSPF Model”. The parameters for the pervious and impervious surfaces in the calibrated model were applied to the site-scale models of the remaining seven sites.

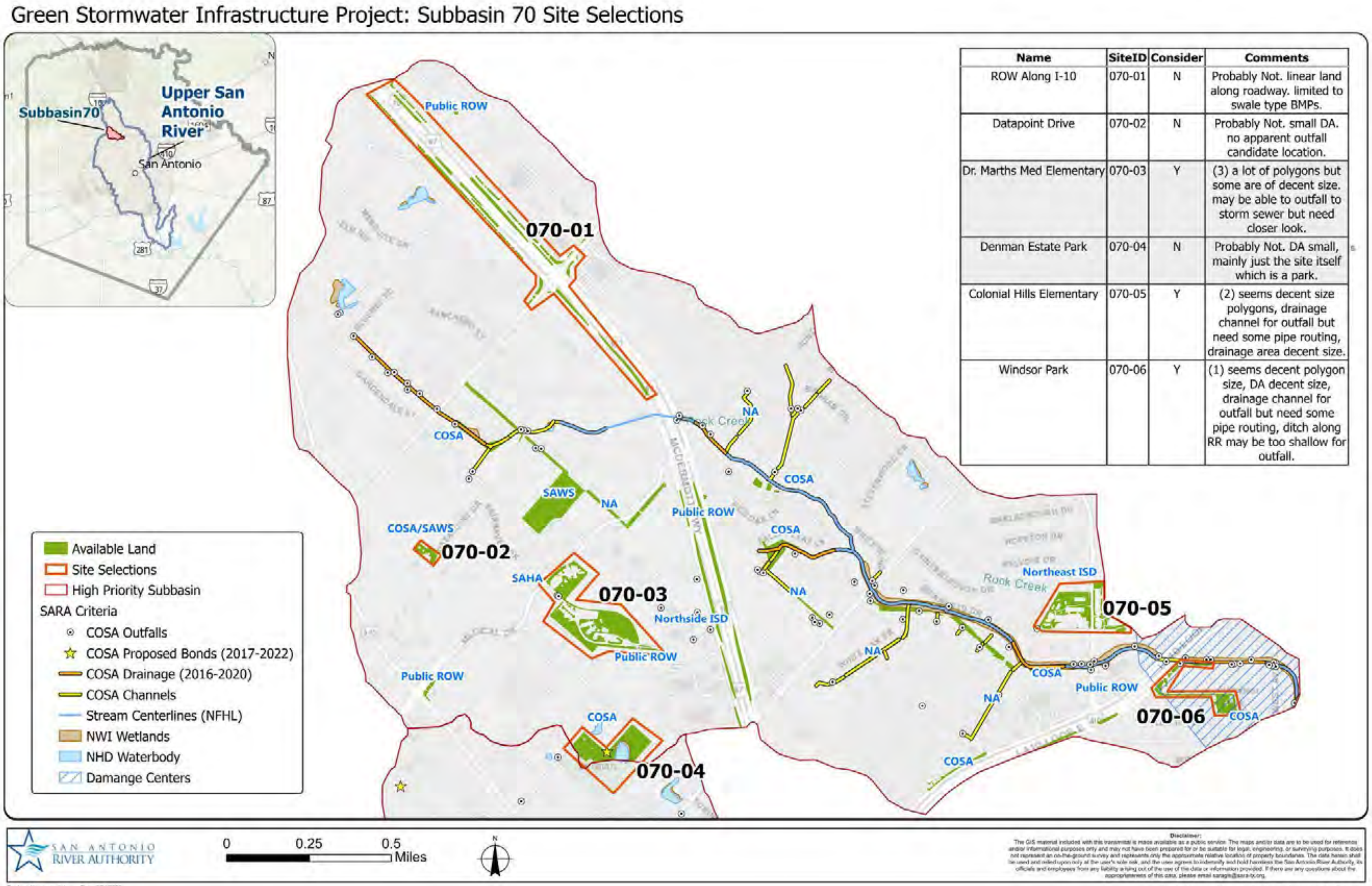
A continuous simulation of the site-scale HSPF models was performed for the period from 01/01/2007 to 12/31/2010. The outputs from the continuous simulation were used to estimate annual average load removal at each BMP site and the effectiveness of each modeled BMP type in reducing constituent loads. The target constituents are *E. coli* and nutrients. This technical memorandum documents the development of the BMP performance evaluation HSPF models and results.

B. Selected Sites for BMP Performance Evaluation Modeling

The BMP sites were selected by the River Authority using GIS and Google Earth imagery to assess the site conditions, LAN analysis on site conditions, LAN BMP Ranking Matrix outlined in Attachment C, and the San Antonio River Basin Low Impact Development Technical Guidance Manual. The chosen sites are listed in Table B-1 and include proposed BMPs for the site. Forty-nine sites in eight subbasins were identified, as documented in the deliverable #10485 Dataset of Potential GSI Projects and are shown below in Exhibits B-1 through B-7 for USAR subbasins 70, 150, 260, 270, 310, 330, and 420, respectively. These potential sites were reviewed internally within the River Authority, with stakeholders in the Bexar Regional Watershed Management (BRWM) Watershed Technical Committee and others identified through the process, such as the San Antonio Housing Authority, for their perceived sustainable return on investment (SROI) and interest. The selected sites are listed in Table B-1 and include proposed GSI BMPs. The BMP site in Subbasin 560 (the Brooks Creek development) was selected in the calibration as documented in Attachment A, "Calibration of Site-Scale HSPF Model". The site was chosen due to the extensive work done with the community in the years leading up to the study and support for GSI by the Brooks Development Authority.

Table B-1 Selected BMP Sites

BMP Selection	Subbasin /Site ID	Name	Site Owner	BMP proposed (without drainage area review)	Object ID
1	070-06	Windsor Park	COSA-Parks	Extended detention basin/swale	6
2	150-05	Terrell Heights – Public ROW	COSA	Bioretention (or swale) with overflow bypass along the street (following current drainage pathway).	12
3	420-09	SAHA - Tampico Street Apt.	SAHA	Using development plan documents, two bioretention areas were chosen to treat a parking lot and rooftop areas prior to entering Alazan Creek.	21
4	310-06	Lee's Creek	COSA	The COSA owned section, 7.4 acres. Swales or bioretention areas to polish runoff before it enters the creek.	29
5	270-06	General McMullen and Dartmouth (Rosedale Park)	COSA	Infiltration rain garden without an underdrain, swale, or bioretention to treat street or parking runoff prior to entering Apache Creek.	37
6	260-04	Monterrey Park	COSA-Parks	Divert street runoff into park and treat in a bioretention area and/or treat parking lot runoff in center island by converting it to a bioretention area.	42
7	330-01	SAHA - Pin Oak II Apartment	SAHA	Parking lot bioretention or swales between the apartments and parking lots.	49
8	560-06	Brooks – Public ROW	COSA	Swale or bioretention in median ROW	59



Name	SiteID	Consider	Comments
ROW Along I-10	070-01	N	Probably Not. linear land along roadway. limited to swale type BMPs.
Datapoint Drive	070-02	N	Probably Not. small DA. no apparent outfall candidate location.
Dr. Marths Med Elementary	070-03	Y	(3) a lot of polygons but some are of decent size. may be able to outfall to storm sewer but need closer look.
Denman Estate Park	070-04	N	Probably Not. DA small, mainly just the site itself which is a park.
Colonial Hills Elementary	070-05	Y	(2) seems decent size polygons, drainage channel for outfall but need some pipe routing, drainage area decent size.
Windsor Park	070-06	Y	(1) seems decent polygon size, DA decent size, drainage channel for outfall but need some pipe routing, ditch along RR may be too shallow for outfall.

Exhibit B-1 Selected BMP Sites for USAR Subbasin 70

Green Stormwater Infrastructure: Subbasin 150

Name	SiteID	Consider	Comments
Howard Early Childhood Center	150-01	N	Probably Not. small DA. should be a storm sewer along Nacogdochee Rd, but not sure if can outfall to it.
Alamo Heights Junior School	150-02	N	Probably Not. small DA. relatively small polygon size. should be a storm sewer along Nacogdochee Rd, but not sure if can outfall to it.
Scates Park	150-03	N	Probably Not. small DA. no apparent outfall candidate location.
Terrell Hills City Hall	150-04	Y	(1) Drainage ditch nearby (see street view), possible outfall? significant drainage area. but relatively small site.
ROW	150-05	N	Probably Not. no apparent outfall candidate location.

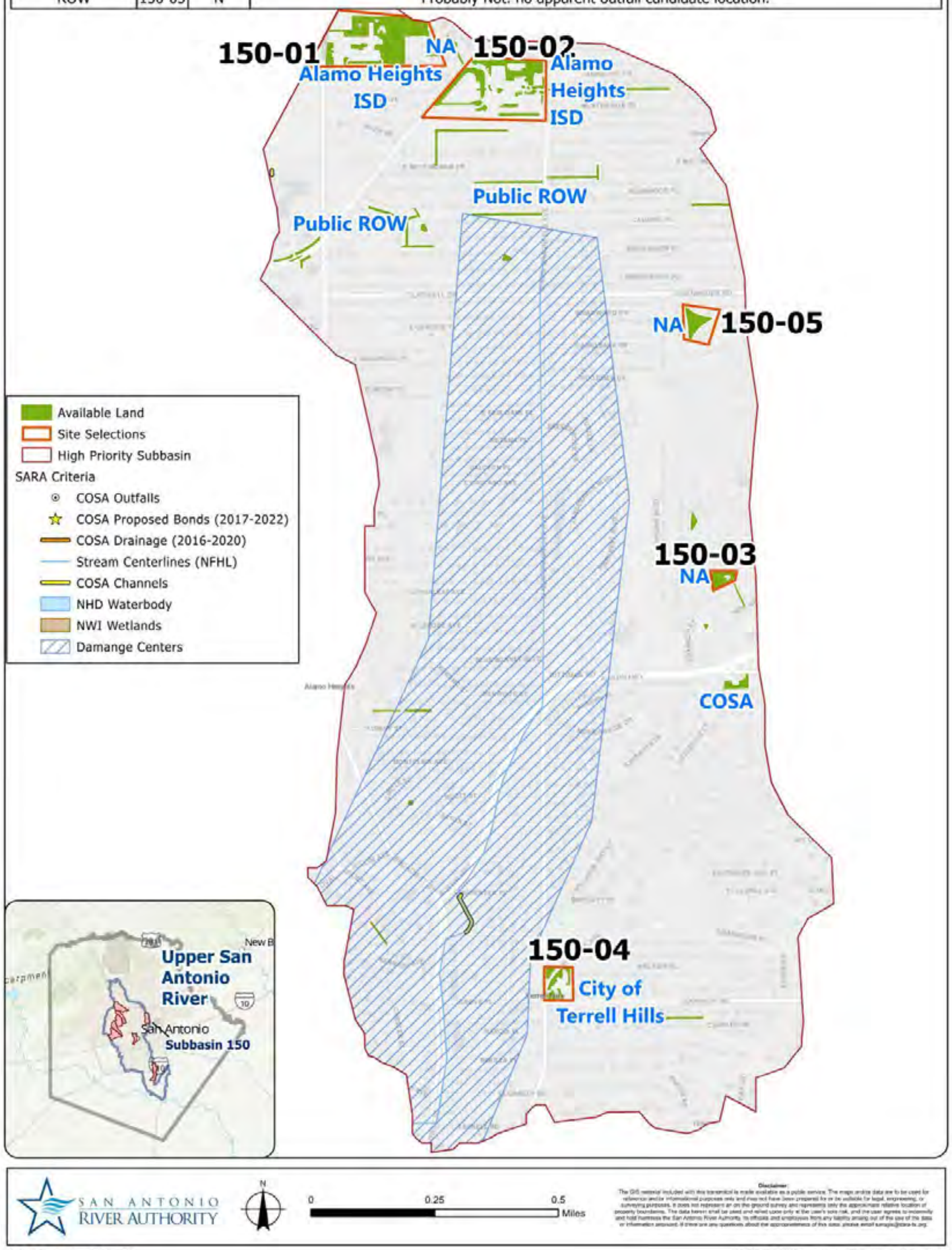
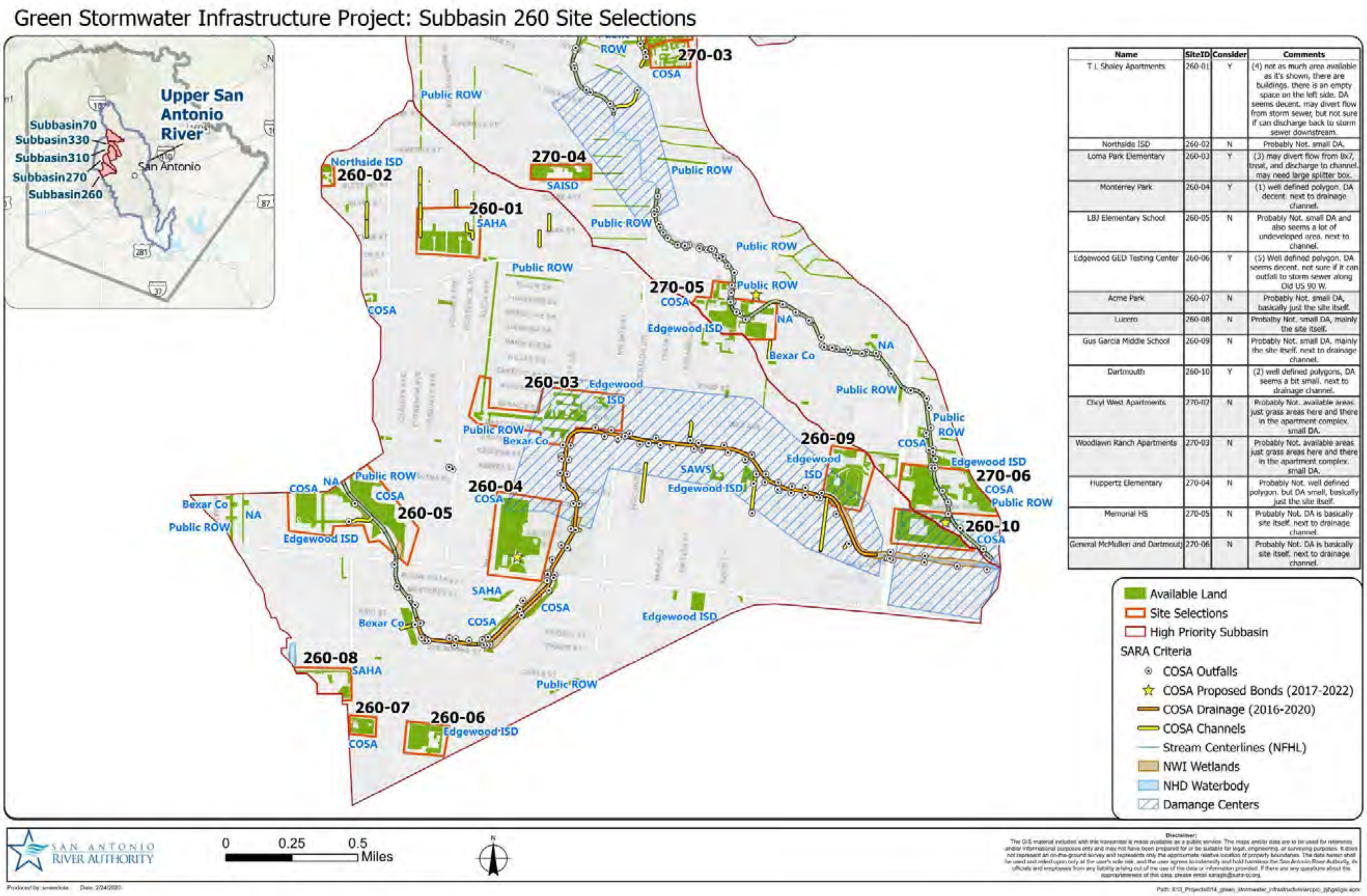
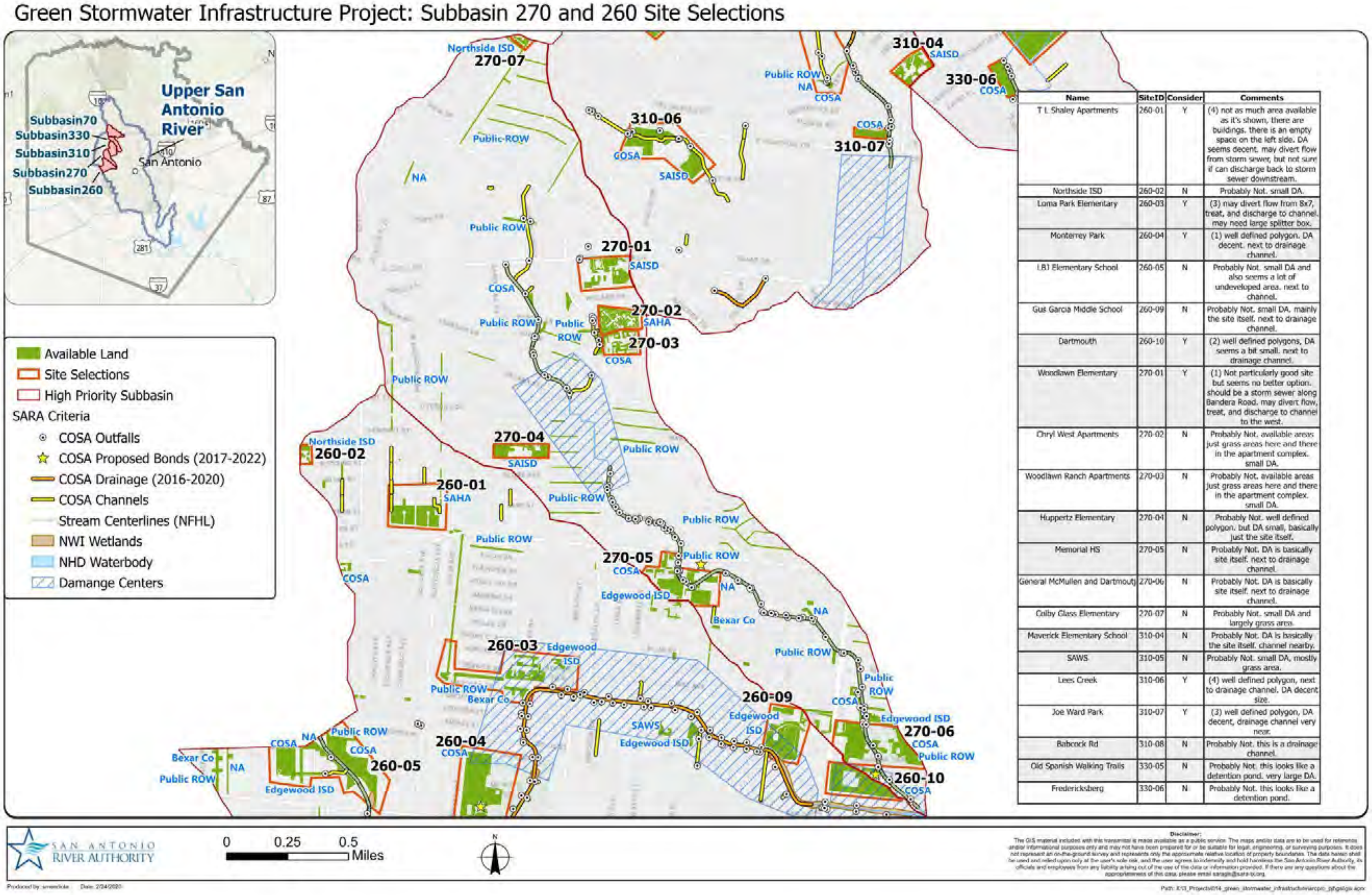


Exhibit B-2 Selected BMP Sites for USAR Subbasin 150



Name	SiteID	Consider	Comments
T L Shaley Apartments	260-01	Y	(4) not as much area available as it's shown, there are buildings. there is an empty space on the left side. DA seems decent. may divert flow from storm sewer, but not sure if can discharge back to storm sewer downstream.
Northside ISD	260-02	N	Probably Not. small DA.
Loma Park Elementary	260-03	Y	(3) may divert flow from 8x7, treat, and discharge to channel. may need large splitter box.
Monterrey Park	260-04	Y	(1) well defined polygon. DA decent. next to drainage channel.
LBJ Elementary School	260-05	N	Probably Not. small DA and also seems a lot of undeveloped area. next to channel.
Edgewood GED Testing Center	260-06	Y	(5) Well defined polygon. DA seems decent. not sure if it can outfall to storm sewer along Old US 90 W.
Acme Park	260-07	N	Probably Not. small DA, basically just the site itself.
Lucero	260-08	N	Probalby Not. small DA, mainly the site itself.
Gus Garcia Middle School	260-09	N	Probably Not. small DA. mainly the site itself. next to drainage channel.
Dartmouth	260-10	Y	(2) well defined polygons, DA seems a bit small. next to drainage channel.
Chryl West Apartments	270-02	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Woodlawn Ranch Apartments	270-03	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Huppertz Elementary	270-04	N	Probably Not. well defined polygon. but DA small, basically just the site itself.
Memorial HS	270-05	N	Probably Not. DA is basically site itself. next to drainage channel.
General McMullen and Dartmoutj	270-06	N	Probably Not. DA is basically site itself. next to drainage channel.

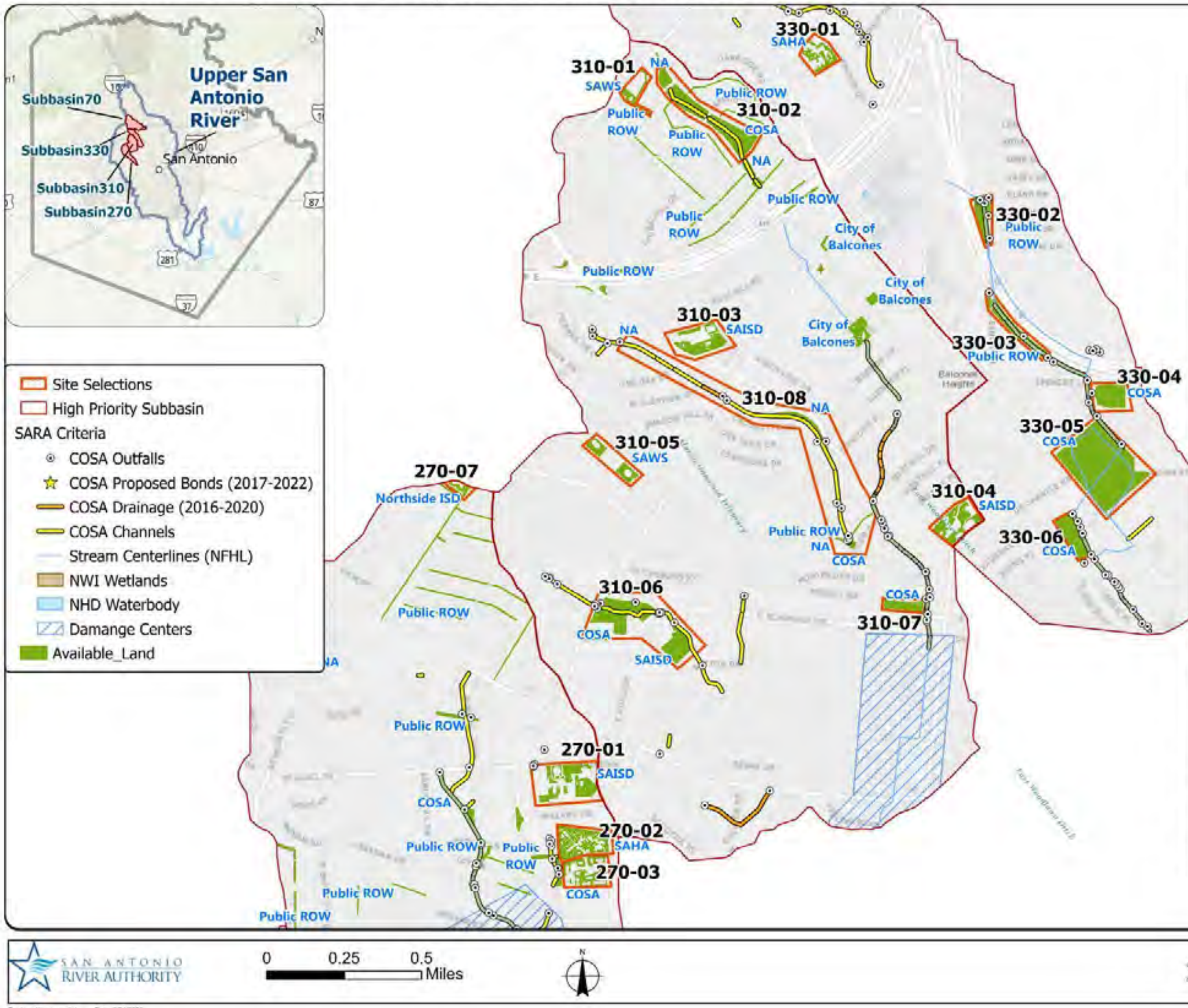
Exhibit B-3 Selected BMP Sites for USAR Subbasin 260



Name	SiteID	Consider	Comments
T L Shaley Apartments	260-01	Y	(4) not as much area available as it's shown, there are buildings. there is an empty space on the left side. DA seems decent. may divert flow from storm sewer, but not sure if can discharge back to storm sewer downstream.
Northside ISD	260-02	N	Probably Not. small DA.
Loma Park Elementary	260-03	Y	(3) may divert flow from 8x7, treat, and discharge to channel. may need large splitter box.
Monterrey Park	260-04	Y	(1) well defined polygon. DA decent. next to drainage channel.
LBJ Elementary School	260-05	N	Probably Not. small DA and also seems a lot of undeveloped area. next to channel.
Gus Garcia Middle School	260-09	N	Probably Not. small DA. mainly the site itself. next to drainage channel.
Dartmouth	260-10	Y	(2) well defined polygons, DA seems a bit small. next to drainage channel.
Woodlawn Elementary	270-01	Y	(1) Not particularly good site but seems no better option. should be a storm sewer along Bandera Road. may divert flow, treat, and discharge to channel to the west.
Chryl West Apartments	270-02	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Woodlawn Ranch Apartments	270-03	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Huppertz Elementary	270-04	N	Probably Not. well defined polygon. but DA small, basically just the site itself.
Memorial HS	270-05	N	Probably Not. DA is basically site itself. next to drainage channel.
General McMullen and Dartmoutj	270-06	N	Probably Not. DA is basically site itself. next to drainage channel.
Colby Glass Elementary	270-07	N	Probably Not. small DA and largely grass area.
Maverick Elementary School	310-04	N	Probably Not. DA is basically the site itself. channel nearby.
SAWS	310-05	N	Probably Not. small DA, mostly grass area.
Lees Creek	310-06	Y	(4) well defined polygon, next to drainage channel. DA decent size.
Joe Ward Park	310-07	Y	(3) well defined polygon, DA decent, drainage channel very near.
Babcock Rd	310-08	N	Probably Not. this is a drainage channel.
Old Spanish Walking Trails	330-05	N	Probably Not. this looks like a detention pond. very large DA.
Fredericksberg	330-06	N	Probably Not. this looks like a detention pond.

Exhibit B-4 Selected BMP Sites for USAR Subbasin 270

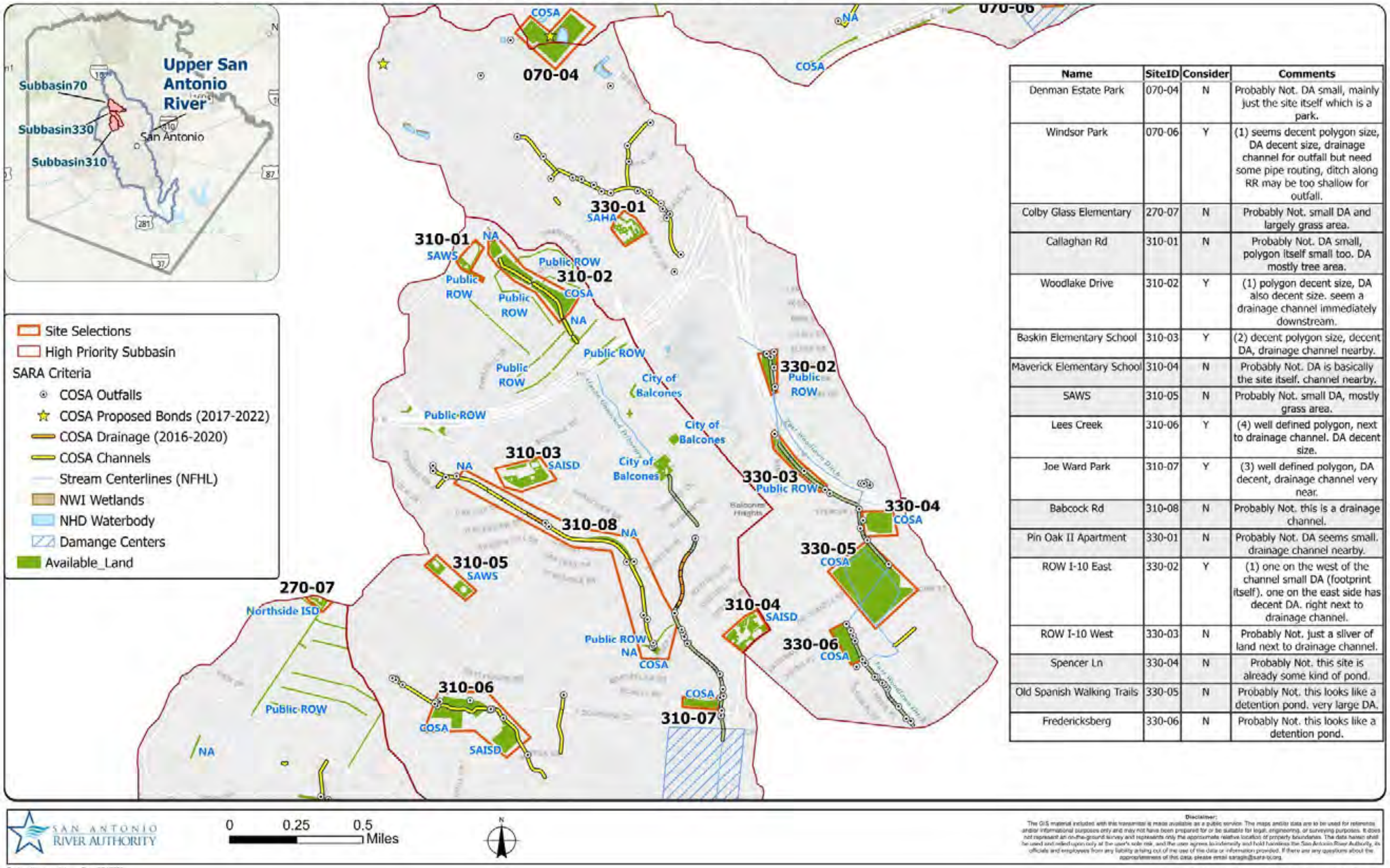
Green Stormwater Infrastructure Project: Subbasin 310 and 270 Site Selections



Name	SiteID	Consider	Comments
Woodlawn Elementary	270-01	Y	(1) Not particularly good site but seems no better option. should be a storm sewer along Bandera Road. may divert flow, treat, and discharge to channel to the west.
Chryl West Apartments	270-02	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Woodlawn Ranch Apartments	270-03	N	Probably Not. available areas just grass areas here and there in the apartment complex. small DA.
Colby Glass Elementary	270-07	N	Probably Not. small DA and largely grass area.
Callaghan Rd	310-01	N	Probably Not. DA small, polygon itself small too. DA mostly tree area.
Woodlake Drive	310-02	Y	(1) polygon decent size, DA also decent size. seem a drainage channel immediately downstream.
Baskin Elementary School	310-03	Y	(2) decent polygon size, decent DA, drainage channel nearby.
Maverick Elementary School	310-04	N	Probably Not. DA is basically the site itself. channel nearby.
SAWS	310-05	N	Probably Not. small DA, mostly grass area.
Lees Creek	310-06	Y	(4) well defined polygon, next to drainage channel. DA decent size.
Joe Ward Park	310-07	Y	(3) well defined polygon, DA decent, drainage channel very near.
Babcock Rd	310-08	N	Probably Not. this is a drainage channel.
Pin Oak II Apartment	330-01	N	Probably Not. DA seems small. drainage channel nearby.
ROW I-10 East	330-02	Y	(1) one on the west of the channel small DA (footprint itself). one on the east side has decent DA. right next to drainage channel.
ROW I-10 West	330-03	N	Probably Not. just a sliver of land next to drainage channel.
Spencer Ln	330-04	N	Probably Not. this site is already some kind of pond.
Old Spanish Walking Trails	330-05	N	Probably Not. this looks like a detention pond. very large DA.
Fredericksberg	330-06	N	Probably Not. this looks like a detention pond.

Exhibit B-5 Selected BMP Sites for USAR Subbasin 310

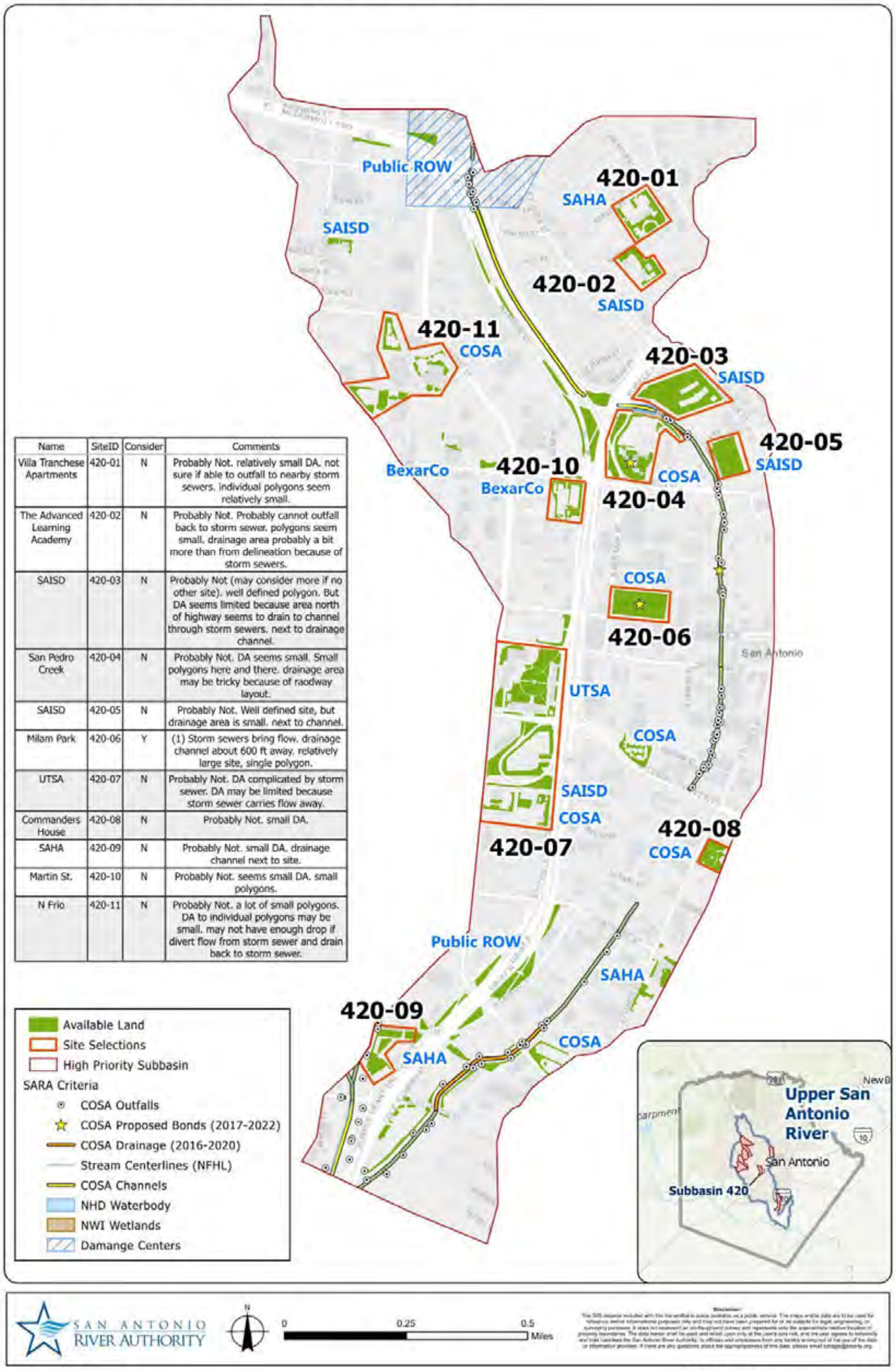
Green Stormwater Infrastructure Project: Subbasin 330 and 310 Site Selections



Name	SiteID	Consider	Comments
Denman Estate Park	070-04	N	Probably Not. DA small, mainly just the site itself which is a park.
Windsor Park	070-06	Y	(1) seems decent polygon size, DA decent size, drainage channel for outfall but need some pipe routing, ditch along RR may be too shallow for outfall.
Colby Glass Elementary	270-07	N	Probably Not. small DA and largely grass area.
Callaghan Rd	310-01	N	Probably Not. DA small, polygon itself small too. DA mostly tree area.
Woodlake Drive	310-02	Y	(1) polygon decent size, DA also decent size. seem a drainage channel immediately downstream.
Baskin Elementary School	310-03	Y	(2) decent polygon size, decent DA, drainage channel nearby.
Maverick Elementary School	310-04	N	Probably Not. DA is basically the site itself. channel nearby.
SAWS	310-05	N	Probably Not. small DA, mostly grass area.
Lees Creek	310-06	Y	(4) well defined polygon, next to drainage channel. DA decent size.
Joe Ward Park	310-07	Y	(3) well defined polygon, DA decent, drainage channel very near.
Babcock Rd	310-08	N	Probably Not. this is a drainage channel.
Pin Oak II Apartment	330-01	N	Probably Not. DA seems small. drainage channel nearby.
ROW I-10 East	330-02	Y	(1) one on the west of the channel small DA (footprint itself). one on the east side has decent DA. right next to drainage channel.
ROW I-10 West	330-03	N	Probably Not. just a sliver of land next to drainage channel.
Spencer Ln	330-04	N	Probably Not. this site is already some kind of pond.
Old Spanish Walking Trails	330-05	N	Probably Not. this looks like a detention pond. very large DA.
Fredericksberg	330-06	N	Probably Not. this looks like a detention pond.

Exhibit B-6 Selected BMP Sites for USAR Subbasin 330

Green Stormwater Infrastructure: Subbasin 420



Name	SiteID	Consider	Comments
Villa Tranchese Apartments	420-01	N	Probably Not. relatively small DA. not sure if able to outfall to nearby storm sewers. individual polygons seem relatively small.
The Advanced Learning Academy	420-02	N	Probably Not. Probably cannot outfall back to storm sewer. polygons seem small. drainage area probably a bit more than from delineation because of storm sewers.
SAISD	420-03	N	Probably Not (may consider more if no other site). well defined polygon. But DA seems limited because area north of highway seems to drain to channel through storm sewers. next to drainage channel.
San Pedro Creek	420-04	N	Probably Not. DA seems small. Small polygons here and there. drainage area may be tricky because of raodway layout.
SAISD	420-05	N	Probably Not. Well defined site, but drainage area is small. next to channel.
Milam Park	420-06	Y	(1) Storm sewers bring flow. drainage channel about 600 ft away. relatively large site, single polygon.
UTSA	420-07	N	Probably Not. DA complicated by storm sewer. DA may be limited because storm sewer carries flow away.
Commanders House	420-08	N	Probably Not. small DA.
SAHA	420-09	N	Probably Not. small DA. drainage channel next to site.
Martin St.	420-10	N	Probably Not. seems small DA. small polygons.
N Frio	420-11	N	Probably Not. a lot of small polygons. DA to individual polygons may be small. may not have enough drop if divert flow from storm sewer and drain back to storm sewer.

Exhibit B-7 Selected BMP Sites for USAR Subbasin 420

C. General Modeling Considerations

The River Authority and LAN discussed and determined to adopt the following general modeling considerations for determining the conceptual layouts of BMPs:

- To be consistent with the City of San Antonio Unified Development Code (UDC, City of San Antonio, 2020), the required water quality volume (WQV) to be captured and treated by a BMP is calculated as 60% of a 1.5-inch design daily rainfall applied to the impervious surface of the drainage area to the BMP, i.e.,

  WQV = 1.5” x 60% x Impervious area

- The BMP types are selected from the BMPs included in the San Antonio River Basin Low Impact Development Technical Design Guidance Manual, Second Edition, May 2019 (SARA LID Manual, 2019).

- Large trees should be preserved.

- Existing park facilities should be preserved.

- The BMP footprint should stay outside of the effective 1% Annual Exceedance Probability (AEP) or 100-year floodplain.

- Only conceptual level of BMP layouts and dimensions are developed in this analysis.

- Detailed flow routing from the drainage area to a BMP or from the BMP outfall to a receiving stream is considered a detailed design element and not conducted in this conceptual level analysis.

- Decay coefficients needed for HSPF modeling of BMPs are obtained from the SARA Enhanced BMP Tool Database. Table C-1 list the decay coefficients and corresponding removal efficiencies for *E. coli* (EC) bacteria and nutrients, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively.

As a part of discussion with the River Authority, LAN conducted a review of historical rainfall records to locate an actual storm event that might represent the 1.5-inch design storm used for WQV calculation. Hourly rainfall data from 01/01/2005 to 03/10/2020 recorded at the San Antonio International Airport (NWS Gage TX12921) were obtained and reviewed, and eight storm events were found to have a total daily rainfall near 1.5 inches. As listed in Table C-2, the 03/20/2012 event is the only one that is exactly 1.500 in.

Exhibit C-1 shows the hourly timeseries of these eight storm events for examination of rainfall distribution through the day. The plots show that the 03/20/2012 event appears to be an appropriate one to use, although it only had a duration of 4 hours. LAN then suggested using the 03/20/2012 storm event if a design storm is needed for modeling BMP, and the River Authority approved the suggestion in May

2020. Note that per the QAPP, this BMP performance evaluation modeling used the 2007 to 2010 hourly rainfall for continuous simulation so the 1.5" design storm was only used for WQV calculations.

Table C-1 Removal Efficiencies and Decay Coefficients

BMP	Parameter	BACT	ORGN	NH3N	NO3N	ORGP	ORTHOP
Bioswale	Removal efficiency (%)	70.0%	18.6%	62.4%	51.0%	21.3%	21.3%
	Decay coeff. (1/day)	1.2048	0.2064	0.9792	0.7128	0.2400	0.2400
Extended detention	Removal efficiency (%)	78.0%	2.1%	23.0%	23.2%	63.8%	63.8%
	Decay coeff. (1/day)	1.5144	0.0216	0.2616	0.2640	1.0152	1.0152
Bioretention large	Removal efficiency (%)	70.0%	18.6%	86.0%	76.0%	69.0%	69.0%
	Decay coeff. (1/day)	1.2048	0.2064	1.9656	1.428	1.1712	1.1712
Bioretention average	Removal efficiency (%)	70.0%	18.6%	62.4%	51.0%	21.3%	21.3%
	Decay coeff. (1/day)	1.2048	0.2064	0.9792	0.7128	0.2400	0.2400

Table C-2 Historical Storm Events Matching 1.5 in/day Design Storm

San Antonio International Airport,
TX12921
(01/01/2005 - 03/10/2020)

Date	Rainfall (in/day)
10/10/2006	1.521
03/30/2007	1.514
04/15/2010	1.490
01/09/2011	1.511
03/20/2012	1.500
06/09/2014	1.493
05/17/2015	1.525
10/31/2018	1.511

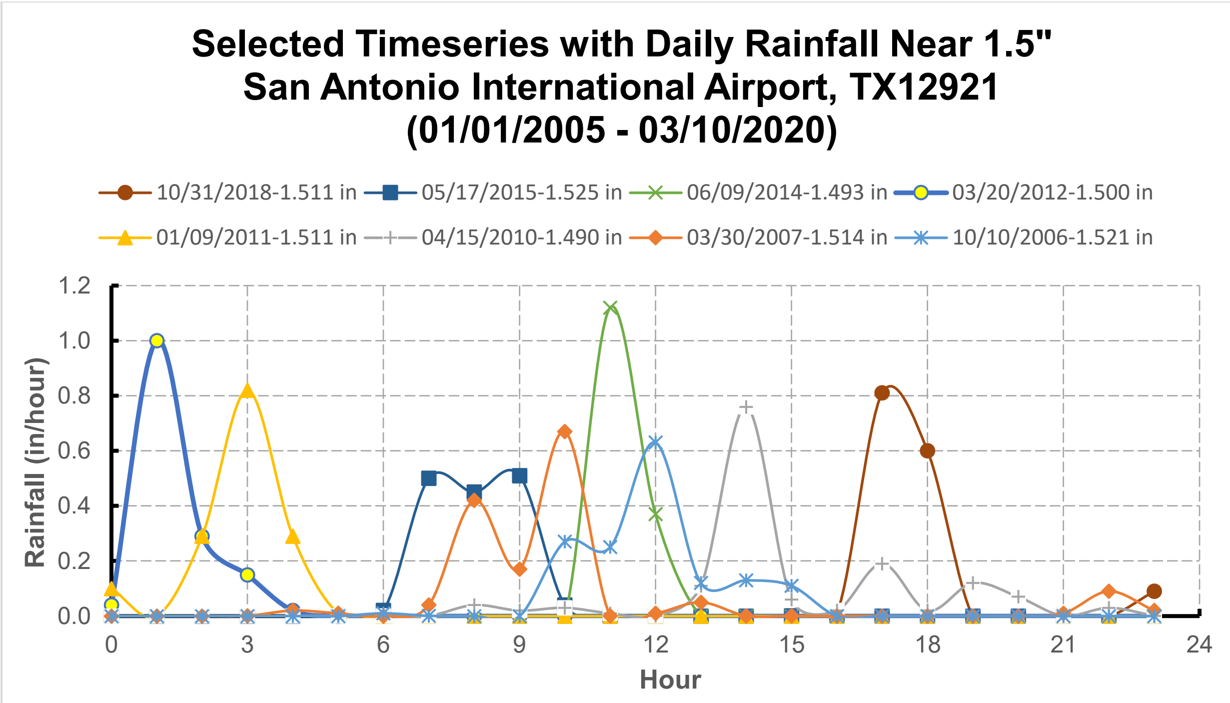


Exhibit C-1 Hourly Timeseries of Historical Storm Events Matching 1.5 in/day Design Storm

D. HSPF Bug Fixing and Code Upgrade

During the BMP Performance Evaluation modeling of a bioswale BMP in USAR Subbasin 70, as represented in Exhibit D-1, the River Authority /LAN team found and confirmed a bug in the HSPF program. The issue is illustrated in Exhibits D-2 and D-3 that show the outputs of RCHRES1 and RCHRES2, respectively, of the bioswale BMP. RCHRES is an operation unit in HSPF representing a water body such as a stream reach or a reservoir.

As shown in Exhibit D-1, the outflow from a Swale and Soil Media RCHRES is through an exit in the HSPF model while the down flow to the underdrain layer is through another exit. As shown in Exhibit D-2, the HSPF modeled sum of the bacteria outflows from the individual exits (ODQAL-EXIT1 and ODQAL-EXIT2) does not match the total bacteria outflow (TROQAL). The problem appears to be that when the volume (VOL) of the RCHRES is zero, the bacteria outflow (ODQAL-EXIT1) is zero even though the outflow (OVOL-1) is not zero. In Exhibit D-3, the HSPF modeled sums of the individual exits for the flow (OVOL-1 and OVOL-2) and the load (ODQAL-EXIT1 and ODQAL-EXIT2) are both zero. But these are inconsistent with the total outflow (ROVOL) and bacteria outflow (TROQAL) which are both non-zero.

- Total inflow (Q_{in}) to BMP
- Overflow (Q_{OF})
- Ground infiltration (Q_{Infil})
  Outflow through underdrain layer (Q_{Und}), combines with bypass flow to become the total outflow (Q_{Out})

The bug was reported to the HSPF development team, RESPEC (formerly AQUA TERRA Consultants). They confirmed and fixed the bug, and then upgraded the code and issued a new HSPF plugin (HSPF12.5plugin.2020.07, HSPF is installed as a plug in to the EPA BASINS).

LAN worked with RESPEC during the bug fixing process and conducted testing of the revised HSPF code/plugin. The discovery, fixing, and testing of this HSPF bug was reported to TCEQ by the River Authority and included in a QAPP Amendment. TCEQ reviewed and approved the Amendment on 07/08/2020 to allow the BMP performance evaluation modeling to resume.

While the majority of the bug has been fixed, a minor issue remains when the outflow is near zero, as shown in Exhibit D-4. RESPEC determined that investigating and resolving this very small issue would take substantial effort because the values involved are so small The River Authority and LAN discussed the matter and determined that because this minor bug only occurs at very small flow volumes and has insignificant impact to the results, it would not be necessary to fix this small bug.

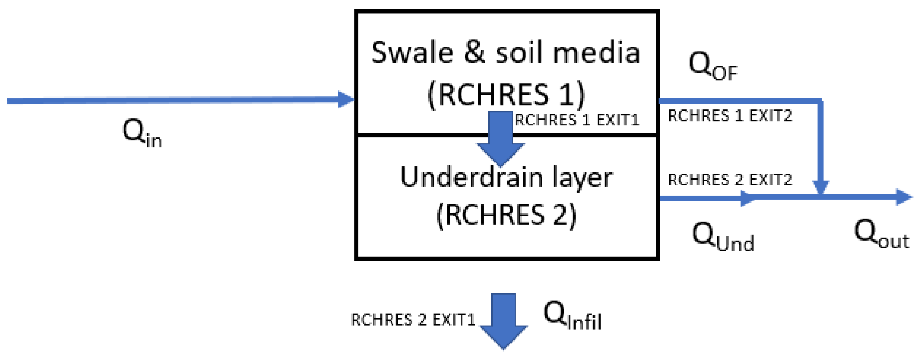


Exhibit D-1 HSPF Modeling of a Bioswale

Exhibit D-2 Outputs of RCHRES1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Vol of water	Sum of	Vol of wat	Vol of outflow	Vol of outflow	Total vol	Total storage	Total inflow	Decay of	Outflow of	Outflow of	Totral outflow	
2		in RCHRES	inflow to	lost by	thru exit 1	thru exit 2	of outflow	of QUAL in	of QUAL	QUAL	QUAL thru	QUAL thru	of QUAL	
3			RCHRES	evap	(to underdrain	(overflow)		RCHRES			exit 1	exit 2		
4					layer)						(to underdrain	(overflow)		
5											layer)			
6	Time Series List													
7	History 1	from UpperS/	from Uppe	from Uppe	from UpperSAR	from UpperSA	from Uppe	from UpperSAR_	from UpperSAR_	from UpperSAR_	from UpperSAR_HSPF	from UpperSAR_HSPF	from UpperSAR_HSPF10c.hbn	
8	Constituent	VOL	IVOL	VOLEV	OVOL-1	OVOL-2	ROVOL	E. COLI-RRQAL	E. COLI-TIQAL	E. COLI-DDQAL-	E. COLI-ODQAL-EXIT1	E. COLI-ODQAL-EXIT2	E. COLI-TROQAL	
9	Id	1	15	17	19	20	18	76	78	85	88	93	87	
10	Location	R:71	R:71	R:71	R:71	R:71	R:71	R:71	R:71	R:71	R:71	R:71	R:71	
11	Sum	3.376	0.91727	0.003229	0.7576	0.15643	0.91404	609,360	333,740	30,305	156,900	11,565	303,440	
12	1/1/2007 1:00	0	2.05E-05	0	0.00002052	0	2.05E-05	0	6.0667	0	0	0	6.0667	
5833	8/31/2007 14:00	0.010305	0.005744	3.9E-05	0.0028678	0	0.002868	9,060.80	3,462.20	466.46	2,651.20	0	2,651.20	
5834	8/31/2007 15:00	0.010075	0.002676	3.9E-05	0.0028678	0	0.002868	7,534	1,116	387.86	2,254.90	0	2,254.90	
5835	8/31/2007 16:00	0.0086149	0.001436	2.83E-05	0.0028678	0	0.002868	5,733.30	501.24	295.16	2,006.80	0	2,006.80	
5836	8/31/2007 17:00	0.0065834	0.000852	1.59E-05	0.0028678	0	0.002868	3,976.70	269.58	204.73	1,821.50	0	1,821.50	
5837	8/31/2007 18:00	0.0042572	0.000545	3.51E-06	0.0028678	0	0.002868	2,352.10	162.41	121.09	1,666	0	1,666	
5838	8/31/2007 19:00	0.0017587	0.000369	0	0.0028678	0	0.002868	934.33	105.81	0	1,523.50	0	1,523.50	
5839	8/31/2007 20:00	0	0.000262	0	0.0020205	0	0.002021	0	73.005	0	0	0	1,007.30	
5840	8/31/2007 21:00	0	0.000192	0	0.00019248	0	0.000192	0	52.637	0	0	0	52.637	
5841	8/31/2007 22:00	0	0.000146	0	0.00014579	0	0.000146	0	39.296	0	0	0	39.296	
5842	8/31/2007 23:00	0	0.000113	0	0.0001132	0	0.000113	0	30.175	0	0	0	30.175	
5843	39326	0	8.98E-05	0	0.00008976	0	8.98E-05	0	23.719	0	0	0	23.719	
5844														
5845			sum of OVOL-1 and OVOL-2 =			0.91403	same as ROVOL, ok.		sum of ODQAL-EXIT1 and ODQAL-EXIT2 =			168,465	not the same as TROQAL???	
5846														
5847											E. COLI-ODQAL-EXIT1 only shows values when VOL is not zero.			

Exhibit D-3 Outputs of RCHRES2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Vol of wat	Sum of	Vol of wat	Vol of out	Vol of out	Total vol	Total storage	Total inflow	Decay of	Outflow of	Outflow of	Totral outflow	
2		in RCHRES	inflow to	lost by	thru exit 1	thru exit 2	of outflow	of QUAL in	of QUAL	QUAL	QUAL thru	QUAL thru	of QUAL	
3			RCHRES	evap	(to soil be	(overflow)		RCHRES			exit 1	exit 2		
4											(to soil below)	(overflow)		
5														
6	Time Series List													
7	History 1	from Uppe	from UpperS	from Uppe	from Uppe	from Uppe	from Uppe	from UpperSAF	from UpperSAF	from UpperSAF	from UpperSAF	from UpperSAF	from UpperSAR_HSPF10c.hbn	
8	Constituent	VOL	IVOL	VOLEV	OVOL-1	OVOL-2	ROVOL	E. COLI-RRQAL	E. COLI-TIQAL	E. COLI-DDQAL	E. COLI-ODQAL	E. COLI-ODQAL	E. COLI-TROQAL	
9	Id	316	330	332	334	335	333	391	393	400	403	408	402	
10	Location	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	
11	Sum	63.6	0.7576	0.071816	0	0	0.67199	1,015,600	156,900	52,284	0	0	100,490	
12	1/1/2007 1:00	2.05E-05	0.00002052	0	0	0	0	0	0	0	0	0	0	
13	1/1/2007 2:00	3.86E-05	0.00001809	0	0	0	0	0	0	0	0	0	0	
5836	8/31/2007 17:00	0.0138	0.0028678	1.59E-05	0	0	0.002852	6,584.90	1,821.50	339	0	0	1,430.90	
5837	8/31/2007 18:00	0.0138	0.0028678	3.51E-06	0	0	0.002864	6,498.20	1,666	334.54	0	0	1,418.20	
5838	8/31/2007 19:00	0.0138	0.0028678	0	0	0	0.002868	6,316.40	1,523.50	325.18	0	0	1,380.20	
5839	8/31/2007 20:00	0.0138	0.0020205	0	0	0	0.002021	5,239.90	0	269.76	0	0	806.7	
5840	8/31/2007 21:00	0.0138	0.00019248	0	0	0	0.000193	4,914.80	0	253.02	0	0	72.088	
5841	8/31/2007 22:00	0.0138	0.00014579	0	0	0	0.000146	4,625.30	0	238.12	0	0	51.38	
5842	8/31/2007 23:00	0.0138	0.0001132	0	0	0	0.000113	4,363.10	0	224.62	0	0	37.633	
5843	39326	0.0138	0.00008976	0	0	0	8.98E-05	4,122.60	0	212.24	0	0	28.195	
5844														
5845			sum of OVOL-1 and OVOL-2 =			0	???		sum of ODQAL-EXIT1 and ODQAL-EXIT2 =			0	???	
5846														
5847										IVOL of R:72 same as OVOL-1 of R:71.				
5848										TIQAL of R:72 same as ODQAL-EXIT1 of R:71.				
5849										But as shown, there are times when there				
5850										are inflow but no associated EC load.				

Exhibit D-4 Outputs of RCHRES2 with Remaining Issue

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Time Series List													
2	History 1	from Uppe	from Uppe	from Uppe	from Uppe	from Uppe	from Uppe	from UpperSAR	from UpperSAR	from UpperSAR	from UpperSAR	from UpperSAR	from UpperSAR_HSPF10	
3	Constituent	VOL	IVOL	VOLEV	OVOL-1	OVOL-2	ROVOL	E. COLI-RRQAL	E. COLI-TIQAL	E. COLI-DDQAL-	E. COLI-ODQAL-	E. COLI-ODQAL-	E. COLI-TROQAL	
4	Id	316	330	332	334	335	333	391	393	400	403	408	402	
5	Location	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	R:72	
6	Sum	237.89	1.7099	0.30642	0	1.3953	1.3953	10,856,000	878,670	524,450	0	353,210	354,220	
7	1/1/2007 1:00	2.05E-05	2.05E-05	0	0	0	0	6.0667	6.0667	0	0	0	0	
8	1/1/2007 2:00	3.86E-05	1.81E-05	0	0	0	0	11.405	5.3383	0	0	0	0	
9	1/1/2007 3:00	5.46E-05	1.6E-05	0	0	0	0	16.13	4.7253	0	0	0	0	
10	1/1/2007 4:00	6.89E-05	1.43E-05	0	0	0	0	20.336	4.2053	0	0	0	0	
7234	10/29/2007 4:00	8.3E-07	7E-08	0	0	0	0	1.6969	0.14356	0	0	0	0	
7235	10/29/2007 5:00	9E-07	6.90E-08	0	0	0	0	1.8385	0.14155	0	0	0	0	
7236	10/29/2007 6:00	9.7E-07	6.80E-08	0	0	0	0	1.9781	0.13958	0	0	0	0	
7237	10/29/2007 7:00	0	6.70E-08	1.03E-06	0	0	0	0	0.13765	0	0	0	2.1157	
7238	10/29/2007 8:00	6.60E-08	6.60E-08	0	0	0	0	0.13576	0.13576	0	0	0	0	
7239	10/29/2007 9:00	0	6.50E-08	1.3E-07	0	0	0	0	0.1339	0	0	0	0.26966	
7240	10/29/2007 10:00	6.40E-08	6.40E-08	0	0	0	0	0.13208	0.13208	0	0	0	0	
7241	10/29/2007 11:00	0	6.40E-08	1.3E-07	0	0	0	0	0.13029	0	0	0	0.26238	
7242	10/29/2007 12:00	6.30E-08	6.30E-08	0	0	0	0	0.12854	0.12854	0	0	0	0	
7243	10/29/2007 13:00	0	6.20E-08	1.2E-07	0	0	0	0	0.12682	0	0	0	0.25536	
7244	10/29/2007 14:00	6.10E-08	6.10E-08	0	0	0	0	0.12513	0.12513	0	0	0	0	
7245	10/29/2007 15:00	0	6E-08	1.2E-07	0	0	0	0	0.12347	0	0	0	0.24861	
7246	10/29/2007 16:00	5.90E-08	5.90E-08	0	0	0	0	0.12185	0.12185	0	0	0	0	
7247	10/29/2007 17:00	0	5.90E-08	1.2E-07	0	0	0	0	0.12025	0	0	0	0.2421	
7248	10/29/2007 18:00	5.80E-08	5.80E-08	0	0	0	0	0.11868	0.11868	0	0	0	0	
7249	10/29/2007 19:00	1.2E-07	5.70E-08	0	0	0	0	0.23583	0.11714	0	0	0	0	
7250	10/29/2007 20:00	1.7E-07	5.60E-08	0	0	0	0	0.35146	0.11563	0	0	0	0	

E. USAR Subbasin 70 BMP Performance Evaluation Modeling

Site Description and Land Uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 70 is Windsor Park as shown in Exhibit E-1. The park is located between the Union Pacific Railroad and Windham Drive. Rock Creek is located at about 500 ft to the north of the park flowing in a west-east direction. Existing facilities in the park include a playscape, a tennis court, and a soccer field with goal posts. There is substantial open space in the park available for placing stormwater BMPs.

The drainage area to Windsor Park was delineated using Arc Hydro and the DEM data provided by the River Authority and determined to be 20.02 acres. As shown in Exhibit E-2, the land use in the delineated drainage area includes mostly single-family residential, some transportation, and some meadow, and stormwater runoff from the area is draining toward Windsor Park from the west.

The land uses and their corresponding impervious cover (IC) percentages from the 2017 land use data provided by the River Authority are used to determine the pervious and impervious areas within the delineated drainage area, as listed in Table E-1.

Table E-1 Land Uses of Subbasin 70 BMP Site

Land use	IC%	Pervious Area (ac)	Impervious Area (ac)	Total Area (ac)

Undeveloped Meadow	0	1.96	0	1.96
Residential High Density	65	4.69	8.71	13.40
Transportation	90	0.47	4.19	4.66
TOTAL	64.4	7.12	12.90	20.02

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQV for the selected BMP site is:
1.5"/12 x 0.6 x 12.90 ac x 1.2 = 1.16 ac-ft

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority's LID Manual (SARA, 2019; page B-117).

Following evaluation of site conditions including floodplain boundary and discussion with the River Authority, the layout of two conceptual bioswales (North and South, or N and S) and two extended detention ponds (N and S) were outlined as shown in Exhibit E-3. These BMPs were assumed to function in parallel instead of in upstream-downstream series to allow independent evaluation of the performance of each BMP type and location. Given the storage volumes of the two extended detention ponds, the required WQV would be met. Thus, the bioswales would provide additional volumes than the required WQV and therefore additional treatment for the delineated drainage area.

Exhibit E-1 Selected Site for Subbasin 70 – Windsor Park

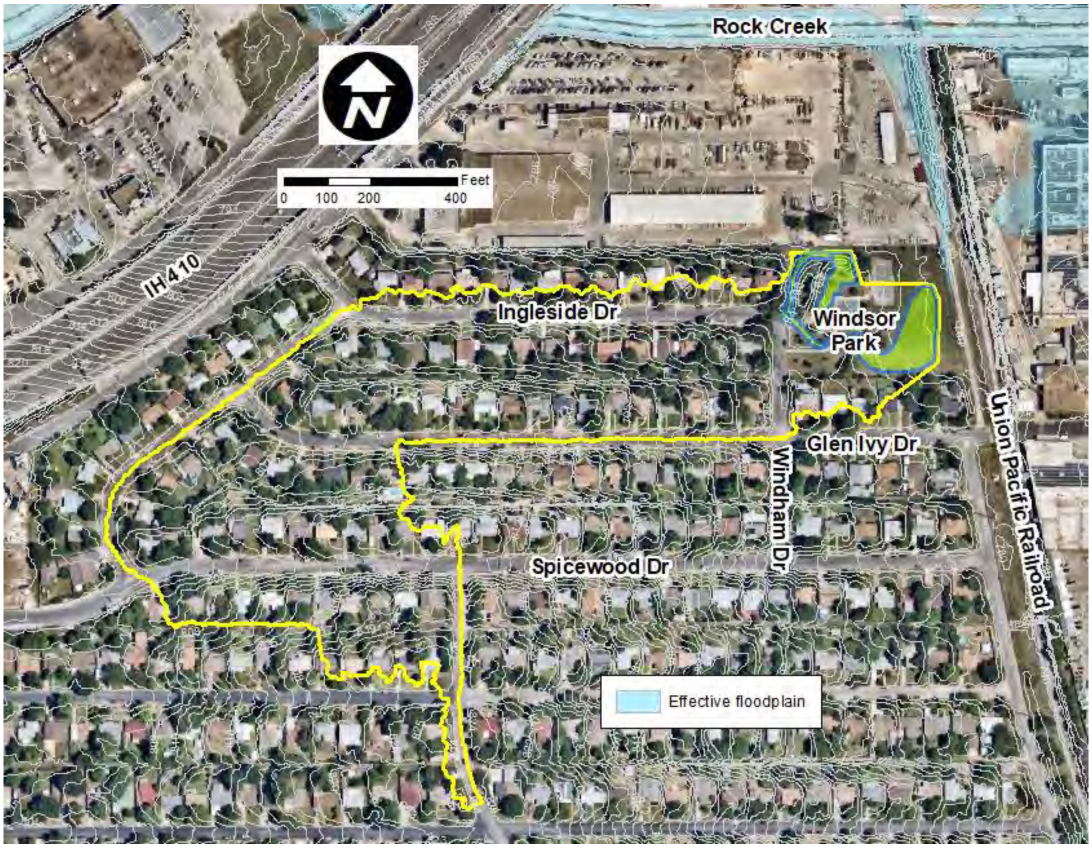


Exhibit E-2 Drainage Area of Subbasin 70 Site

Exhibit E-3 Proposed BMPs on Subbasin 70 Site

Sizing BMPs

Based on site condition and available footprint, the lengths of Bioswale N and Bioswale S are outlined to be 200 and 165 ft, respectively. In the BMP Tool Database, a unit of bioswale is 1,120 ft long that can serve 2.0 acres of drainage area. Thus, Bioswale N and Bioswale S were assumed to serve 0.36 ac (200/1,120 x 2.0) and 0.29 ac (165/1,120 x 2.0), respectively, with a total of 0.65 ac.

With a total drainage area of 20.02 ac and the two bioswales treating 0.65 ac, the two extended detention ponds would treat at least 19.37 ac. This area was split between the two ponds based on the pond volumes listed in Table E-2. Note that, with larger available BMP footprint than required, the total pond volume is 1.384 ac-ft, which is more than the required water quality volume of 1.16 ac-ft. The areas for the various land uses are allocated to the four BMPs as shown in Table E-3 where per and imp indicate pervious and impervious areas, respectively. The WQV and surface area of each BMP is shown in Table E-4.

Table E-2 Extended Detention Pond Volumes and Drainage Areas for Subbasin 70

BMPs	Pond volume (ac-ft)	Drainage area (ac)
Extended detention N	0.249	3.48
Extended detention S	1.135	15.89
TOTAL	1.384	19.37

Table E-3 Drainage Areas and Land Uses for Selected BMP in Subbasin 70

Land use	Bioswale N	Bioswale S	Ex det N	Ex det S	Total
Undeveloped meadow (per)	0.0353	0.0284	0.3414	1.5582	1.96
Residential high density (per)	0.0843	0.0679	0.8154	3.7211	4.69
Residential high density (imp)	0.1566	0.1261	1.5142	6.9106	8.71
Transportation (per)	0.0084	0.0067	0.0810	0.3697	0.47
Transportation (imp)	0.0754	0.0607	0.7290	3.3269	4.19
Total	0.36	0.29	3.48	15.89	20.02

Table E-4 Water Quality Volume and Surface Area of Subbasin 70 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioswale N	0.0628	0.0436
Bioswale S	0.0518	0.0360
Extended detention N	0.2487	0.1115
Extended detention S	1.1350	0.4060
Total	1.4983	0.5971
Required	1.1610	N/A

Note: Surface area is the area at the water level of the WQV.

Modeling Bioswales in HSPF

Exhibit D-1 illustrates how a bioswale is set up in HSPF. Each bioswale includes two components each represented by a HSPF RCHRES. The upper component includes swale vegetation and soil media. The lower component is an underdrain layer. Stormwater runoff entering a bioswale will flow through the soil media into an underdrain layer. Higher flow would overflow the swale. Based on the SSURGO database, the soil at this BMP site is classified as hydrologic soil group (HSG) D, which has a very low infiltration capacity. As a result, no infiltration is assumed to enter the soil below the underdrain layer. When the underdrain layer is full, treated runoff would leave the underdrain and outflow downstream. The total outflow is the sum of the overflow from the swale and soil media and the outflow from the underdrain layer.

Using data listed in Table B-2-1 of the River Authority's LID Manual, the soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4. Page B-158 of the River Authority's LID Manual requires that a bioswale be designed to safely convey the 25-year storm event, and Page B-40 requires that flow velocity generally not exceed 1 ft/sec in mulched swales or 3 ft/sec in grassed swales. Calculations listed in Table E-5 show that the proposed bioswales meet these requirements.

Table E-5 Hydraulic Parameters of Bioswales in USAR Subbasin 70

Hydraulic Parameters	Bioswale N	Bioswale S
Length (ft)	200	165
Drainage area (ac)	0.36	0.29
Bottom width (ft)	5	5
Side slope (xH:1V)	3	3
Depth of swale (ft)	0.75	0.75
Manning n	0.2	0.2
Longitudinal slope	0.02	0.02
25-yr rainfall intensity (in/hr)	11	11
Runoff coefficient	0.67	0.67
25-yr flow (cfs)	2.65	2.14
Flow depth (ft)	0.61 < 0.75 OK	0.54 < 0.75 OK
Cross section area (ft^2)	4.17	3.57
Wetted perimeter (ft)	8.86	8.42
Hydraulic radius (ft)	0.47	0.42
Velocity (ft/s)	0.64 < 1 OK	0.59 < 1 OK

Modeling Extended Detention Ponds in HSPF

The extended detention ponds are required to have a 3:1 side slope. Extended Detention Pond N and S are assumed to have a water depth of 3.5 and 4.0 ft, respectively, when capturing the proposed WQV of 0.249 and 1.135 ac-ft, respectively. The pond is modeled as a RCHRES in HSPF as illustrated in Exhibit E-4, where flow entering the Extended Detention Basin is (Q_{in}), overflow is (Q_{OF}), and flow through the office is (Q_{Orfice}), and the overflow and flow through leave the system in (Q_{Out}). High flow is released via a weir at the top of the pond. The pond volume is drained via an orifice outlet.

The outflow in a FTABLE, i.e. the rating table of a HSPF RCHRES that relates water depth to surface area, total volume, and outflow, was set up per Table B-8-1 in the River Authority's LID Manual. That is, complete drawdown of the WQV would occur within 48 hours but no more than 50% of the WQV would drain from the pond within the first 24 hours. It is assumed that the actual design of the outlet system will be done in the detailed design.

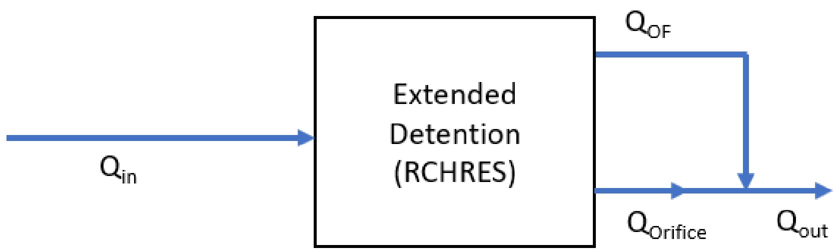


Exhibit E-4 Extended Detention

Development of HSPF Model Files

The original USAR subbasin-scale watershed model with simulation period from 2007 to 2010 was modified by applying model parameters from the site-scale model calibration effort and adding selected BMPs to be modeled. For the Subbasin 70 site, the HSPF model modifications are summarized in detailed steps in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table E-6 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for each of the four Subbasin 70 BMP layouts. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Table E-6 EC Concentrations of Subbasin 70 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioswale N	72,387	17,981	9,855	13,819
Bioswale S	72,394	17,981	9,609	13,725

Extended detention N	72,383	17,981	72,668	12,848
Extended detention S	72,384	17,982	71,098	13,001
Overall	72,384	17,982	71,014	13,044

Table E-6 shows that outflow EC geomeans of the bioswales are lower than the inflow, and Extended Detention S BMP also has a slightly lower outflow geomean than the inflow. However, for Extended Detention N, the outflow geomean is slightly higher than the inflow. This is possible because the ponds can hold higher concentration stormwater and release the water slowly during the dry weather after storm events when the flow is smaller. That is, a large pond can extend the effects of higher EC loads in stormwater after each storm event resulting in the overall geomean to be slightly higher than the inflow. However, it is critical to note that the outflow flow-weighted geomeans are all lower than the inflow reflecting the reduction in EC loads during storm events.

Tables E-7 to E-10 list the model output annual inflows and outflows of each of the four BMP layouts in Subbasin 70 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed by each BMP and the corresponding removal percentages (or BMP performance) are also listed. Table E-11 shows the same set of information but for the 4-year total.

The constituent removal percentages were calculated in two approaches – based on individual input to a BMP and based on the total input coming from the drainage area. The loads removed and removal percentages calculated are summarized in Table E-12 for easier comparison.

For the approach based on individual input to a BMP, the percent removal represents only the performance of the BMP in removing only the flow and loads that can enter the BMP. While this is the standard approach when evaluating BMP performance, it can be misleading when comparing BMPs because the total input to BMPs are not the same. For example, Table E-12 shows that bioswales have a higher percentage removal of EC (4-year total about 63%) than the extended detention ponds (4-year total about 30%) if comparing these two BMP types using the percent removal based on individual BMP inflow.

In addition to the difference in decay coefficients between BMP types, the modeling results are also affected by the inflows to a bioswale BMP being detained longer resulting in a longer time for decay to occur. In particular, the underdrain layer was modeled to fill up and overflow and, when the water level was below the top of the underdrain layer, the water was retained in the underdrain layer and decay could continue for a long time resulting in more load removal. Note that 2008 was a dry year, and the inflows were smaller and more likely to be retained in the bioswales. Therefore, the removal percentages are higher in 2008 than the other years.

On the other hand, as listed in Table E-12 under the “Load Removed” columns, a bioswale could remove about 4×10^{11} EC load over the 2007 to 2010 period while an extended detention pond could remove from 2×10^{12} to almost 10^{13} of EC load. Thus, when comparing BMP types, it would be beneficial to also evaluate the percent load removal based on the total input from the drainage area. Because bioswales are sized to only treat only a small portion of the total drainage area, the removal percentages based on total inputs are much smaller (about 1%) than those of the detention ponds. The overall results are dominated by the performance of the extended detention ponds (from 5.4 to 23.7%).

Thus, a complete BMP performance evaluation should not only compare percent load removal data, but also the size, cost, footprint area, etc. associated with the BMPs. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

Table E-7 2007 Flows and Loads of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underdrain (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.5745	0.5745	0.0017	0.5550	0.0178	0.0000	0.0000	0.0178	0.0972	16.9%	0.3%
	Underdrain		0.5550	0.0954		0.4595	0.0000	0.0000	0.4595			
Bioswale S	Swale + Media	0.4626	0.4626	0.0014	0.4485	0.0127	0.0000	0.0000	0.0127	0.0799	17.3%	0.3%
	Underdrain		0.4485	0.0784		0.3701	0.0000	0.0000	0.3701			
Extended detention N		5.5550		0.0361			0.0000	0.0000	5.5189	0.0361	0.6%	0.1%
Extended detention S		25.3519		0.1413			0.0000	0.0000	25.2107	0.1413	0.6%	0.4%
Total		31.9441		0.3545			0.0000	0.0000	31.5896	0.3544		1.1%

Annual rainfall (in)	46.238
drainage area (ac)	20.02
overall runoff coeff	0.414

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underdrain (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	263,776	263,776	4,946	257,510	1,320	0	0	1,320	159,644	60.5%	1.1%
	Underdrain		257,510	154,698		102,812	0	0	102,812			
Bioswale S	Swale + Media	212,391	212,391	3,628	207,787	976	0	0	976	129,538	61.0%	0.9%
	Underdrain		207,787	125,909		81,877	0	0	81,877			
Extended detention N		2,550,473		750,332			0	0	1,800,141	750,333	29.4%	5.1%
Extended detention S		11,639,892		3,324,641			0	0	8,315,250	3,324,642	28.6%	22.7%
Total		14,666,532		4,364,155			0	0	10,302,375	4,364,157		29.8%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	1.0870	1.0870	0.0027	1.0806	0.0037	0.0000	0.0000	0.0037	0.4765	43.8%	0.8%
	Underdrain		1.0806	0.4739		0.6067	0.0000	0.0000	0.6067			
Bioswale S	Swale + Media	0.8752	0.8752	0.0019	0.8706	0.0027	0.0000	0.0000	0.0027	0.3899	44.5%	0.6%
	Underdrain		0.8706	0.3880		0.4826	0.0000	0.0000	0.4826			
Extended detention N		10.5100		0.0625			0.0000	0.0000	10.4475	0.0625	0.6%	0.1%
Extended detention S		47.9654		0.2728			0.0000	0.0000	47.6927	0.2728	0.6%	0.5%
Total		60.4376		1.2017			0.0000	0.0000	59.2359	1.2017		2.0%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.5335	0.5335	0.0229	0.4988	0.0119	0.0000	0.0000	0.0119	0.2879	54.0%	1.0%
	Underdrain		0.4988	0.2650		0.2338	0.0000	0.0000	0.2338			
Bioswale S	Swale + Media	0.4296	0.4296	0.0180	0.4033	0.0083	0.0000	0.0000	0.0083	0.2342	54.5%	0.8%
	Underdrain		0.4033	0.2162		0.1870	0.0000	0.0000	0.1870			
Extended detention N		5.1585		0.4455			0.0000	0.0000	4.7130	0.4454	8.6%	1.5%
Extended detention S		23.5422		1.9740			0.0000	0.0000	21.5682	1.9740	8.4%	6.7%
Total		29.6637		2.9416			0.0000	0.0000	26.7222	2.9416		9.9%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.8450	0.8450	0.0195	0.8137	0.0118	0.0000	0.0000	0.0118	0.4444	52.6%	0.9%
	Underdrain		0.8137	0.4249		0.3888	0.0000	0.0000	0.3888			
Bioswale S	Swale + Media	0.6804	0.6804	0.0151	0.6570	0.0083	0.0000	0.0000	0.0083	0.3618	53.2%	0.8%
	Underdrain		0.6570	0.3467		0.3103	0.0000	0.0000	0.3103			
Extended detention N		8.1702		0.6669			0.0000	0.0000	7.5033	0.6669	8.2%	1.4%
Extended detention S		37.2873		2.9438			0.0000	0.0000	34.3435	2.9438	7.9%	6.3%
Total		46.9829		4.4169			0.0000	0.0000	42.5660	4.4169		9.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3489	0.3489	0.0010	0.3467	0.0011	0.0000	0.0000	0.0011	0.1567	44.9%	0.8%
	Underdrain		0.3467	0.1557		0.1910	0.0000	0.0000	0.1910			
Bioswale S	Swale + Media	0.2809	0.2809	0.0007	0.2794	0.0008	0.0000	0.0000	0.0008	0.1281	45.6%	0.7%
	Underdrain		0.2794	0.1273		0.1520	0.0000	0.0000	0.1520			
Extended detention N		3.3734		0.6786			0.0000	0.0000	2.6948	0.6786	20.1%	3.5%
Extended detention S		15.3955		2.9927			0.0000	0.0000	12.4028	2.9928	19.4%	15.4%
Total		19.3987		3.9561			0.0000	0.0000	15.4426	3.9561		20.4%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.1418	0.1418	0.0005	0.1404	0.0009	0.0000	0.0000	0.0009	0.0644	45.4%	0.8%
	Underdrain		0.1404	0.0638		0.0766	0.0000	0.0000	0.0766			
Bioswale S	Swale + Media	0.1142	0.1142	0.0004	0.1131	0.0006	0.0000	0.0000	0.0006	0.0526	46.1%	0.7%
	Underdrain		0.1131	0.0522		0.0609	0.0000	0.0000	0.0609			
Extended detention N		1.3709		0.2756			0.0000	0.0000	1.0953	0.2756	20.1%	3.5%
Extended detention S		6.2565		1.2153			0.0000	0.0000	5.0412	1.2153	19.4%	15.4%
Total		7.8833		1.6079			0.0000	0.0000	6.2755	1.6078		20.4%

Table E-8 2008 Flows and Loads of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underdrain (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.1129	0.1129	0.0001	0.1128	0.0000	0.0000	0.0000	0.0000	0.0658	58.3%	1.0%
	Underdrain		0.1128	0.0658		0.0471	0.0000	0.0000	0.0471			
Bioswale S	Swale + Media	0.0909	0.0909	0.0000	0.0909	0.0000	0.0000	0.0000	0.0000	0.0540	59.4%	0.9%
	Underdrain		0.0909	0.0540		0.0369	0.0000	0.0000	0.0369			
Extended detention N		1.0915		0.0082			0.0000	0.0000	1.0832	0.0082	0.8%	0.1%
Extended detention S		4.9813		0.0327			0.0000	0.0000	4.9486	0.0327	0.7%	0.5%
Total		6.2766		0.1608			0.0000	0.0000	6.1158	0.1608		2.6%

Annual rainfall (in)	14.06
drainage area (ac)	20.02
overall runoff coeff	0.268

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underdrain (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	101,244	101,244	0	101,244	0	0	0	0	81,152	80.2%	1.4%
	Underdrain		101,244	81,152		20,092	0	0	20,092			
Bioswale S	Swale + Media	81,522	81,522	0	81,522	0	0	0	0	65,044	79.8%	1.2%
	Underdrain		81,522	65,044		16,477	0	0	16,477			
Extended detention N		978,941		227,776			0	0	751,164	227,777	23.3%	4.0%
Extended detention S		4,467,712		993,101			0	0	3,474,607	993,104	22.2%	17.6%
Total		5,629,419		1,367,072			0	0	4,262,342	1,367,078		24.3%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.4264	0.4264	0.0000	0.4264	0.0000	0.0000	0.0000	0.0000	0.2918	68.4%	1.2%
	Underdrain		0.4264	0.2918		0.1346	0.0000	0.0000	0.1346			
Bioswale S	Swale + Media	0.3434	0.3434	0.0000	0.3434	0.0000	0.0000	0.0000	0.0000	0.2375	69.2%	1.0%
	Underdrain		0.3434	0.2375		0.1059	0.0000	0.0000	0.1059			
Extended detention N		4.1232		0.0177			0.0000	0.0000	4.1055	0.0177	0.4%	0.1%
Extended detention S		18.8173		0.0759			0.0000	0.0000	18.7415	0.0759	0.4%	0.3%
Total		23.7103		0.6229			0.0000	0.0000	23.0875	0.6228		2.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.1544	0.1544	0.0000	0.1544	0.0000	0.0000	0.0000	0.0000	0.1229	79.6%	1.4%
	Underdrain		0.1544	0.1229		0.0315	0.0000	0.0000	0.0315			
Bioswale S	Swale + Media	0.1243	0.1243	0.0000	0.1243	0.0000	0.0000	0.0000	0.0000	0.0989	79.6%	1.2%
	Underdrain		0.1243	0.0989		0.0254	0.0000	0.0000	0.0254			
Extended detention N		1.4926		0.0781			0.0000	0.0000	1.4146	0.0781	5.2%	0.9%
Extended detention S		6.8120		0.3360			0.0000	0.0000	6.4761	0.3359	4.9%	3.9%
Total		8.5833		0.6358			0.0000	0.0000	7.9475	0.6358		7.4%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.2743	0.2743	0.0000	0.2743	0.0000	0.0000	0.0000	0.0000	0.2101	76.6%	1.4%
	Underdrain		0.2743	0.2101		0.0642	0.0000	0.0000	0.0642			
Bioswale S	Swale + Media	0.2209	0.2209	0.0000	0.2209	0.0000	0.0000	0.0000	0.0000	0.1692	76.6%	1.1%
	Underdrain		0.2209	0.1692		0.0517	0.0000	0.0000	0.0517			
Extended detention N		2.6522		0.1372			0.0000	0.0000	2.5150	0.1373	5.2%	0.9%
Extended detention S		12.1041		0.5909			0.0000	0.0000	11.5133	0.5908	4.9%	3.9%
Total		15.2515		1.1073			0.0000	0.0000	14.1442	1.1073		7.3%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.1341	0.1341	0.0000	0.1341	0.0000	0.0000	0.0000	0.0000	0.0927	69.1%	1.2%
	Underdrain		0.1341	0.0927		0.0414	0.0000	0.0000	0.0414			
Bioswale S	Swale + Media	0.1080	0.1080	0.0000	0.1080	0.0000	0.0000	0.0000	0.0000	0.0754	69.8%	1.0%
	Underdrain		0.1080	0.0754		0.0326	0.0000	0.0000	0.0326			
Extended detention N		1.2964		0.2058			0.0000	0.0000	1.0905	0.2058	15.9%	2.8%
Extended detention S		5.9164		0.8954			0.0000	0.0000	5.0210	0.8954	15.1%	12.0%
Total		7.4548		1.2693			0.0000	0.0000	6.1854	1.2693		17.0%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.0530	0.0530	0.0000	0.0530	0.0000	0.0000	0.0000	0.0000	0.0367	69.2%	1.2%
	Underdrain		0.0530	0.0367		0.0163	0.0000	0.0000	0.0163			
Bioswale S	Swale + Media	0.0427	0.0427	0.0000	0.0427	0.0000	0.0000	0.0000	0.0000	0.0298	69.9%	1.0%
	Underdrain		0.0427	0.0298		0.0128	0.0000	0.0000	0.0128			
Extended detention N		0.5126		0.0814			0.0000	0.0000	0.4312	0.0814	15.9%	2.8%
Extended detention S		2.3392		0.3539			0.0000	0.0000	1.9853	0.3539	15.1%	12.0%
Total		2.9475		0.5018			0.0000	0.0000	2.4457	0.5018		17.0%

Table E-9 2009 Flows and Loads of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underdrain (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3505	0.3505	0.0006	0.3499	0.0000	0.0000	0.0000	0.0000	0.0638	18.2%	0.3%
	Underdrain		0.3499	0.0632		0.2749	0.0000	0.0118	0.2749			
Bioswale S	Swale + Media	0.2822	0.2822	0.0005	0.2818	0.0000	0.0000	0.0000	0.0000	0.0523	18.5%	0.3%
	Underdrain		0.2818	0.0519		0.2202	0.0000	0.0098	0.2202			
Extended detention N		3.3894		0.0177			0.0000	0.0000	3.3717	0.0177	0.5%	0.1%
Extended detention S		15.4685		0.0686			0.0000	0.0000	15.3998	0.0687	0.4%	0.4%
Total		19.4907		0.2025			0.0000	0.0216	19.2666	0.2025		1.0%

Annual rainfall (in)	29.132
drainage area (ac)	20.02
overall runoff coeff	0.401

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underdrain (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	176,853	176,853	2,979	173,874	0	0	0	0	101,870	57.6%	1.0%
	Underdrain		173,875	98,885		74,811	0	172	74,811			
Bioswale S	Swale + Media	142,401	142,401	2,305	140,097	0	0	0	0	82,796	58.1%	0.8%
	Underdrain		140,097	80,486		59,467	0	138	59,467			
Extended detention N		1,710,005		556,560			0	7	1,153,436	556,562	32.5%	5.7%
Extended detention S		7,804,140		2,478,140			0	32	5,325,978	2,478,130	31.8%	25.2%
Total		9,833,399		3,219,353			0	349	6,613,692	3,219,358		32.7%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.7196	0.7196	0.0016	0.7180	0.0000	0.0000	0.0000	0.0000	0.3299	45.9%	0.8%
	Underdrain		0.7180	0.3283		0.3847	0.0000	0.0050	0.3847			
Bioswale S	Swale + Media	0.5794	0.5794	0.0012	0.5782	0.0000	0.0000	0.0000	0.0000	0.2694	46.5%	0.7%
	Underdrain		0.5782	0.2681		0.3060	0.0000	0.0040	0.3060			
Extended detention N		6.9577		0.0498			0.0000	0.0000	6.9079	0.0498	0.7%	0.1%
Extended detention S		31.7536		0.2197			0.0000	0.0002	31.5337	0.2197	0.7%	0.5%
Total		40.0103		0.8688			0.0000	0.0093	39.1322	0.8688		2.2%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3417	0.3417	0.0143	0.3274	0.0000	0.0000	0.0000	0.0000	0.1809	52.9%	1.0%
	Underdrain		0.3274	0.1666		0.1604	0.0000	0.0004	0.1604			
Bioswale S	Swale + Media	0.2751	0.2751	0.0111	0.2640	0.0000	0.0000	0.0000	0.0000	0.1463	53.2%	0.8%
	Underdrain		0.2640	0.1358		0.4778	0.0000	0.0009	0.1279			
Extended detention N		3.3036		0.3583			0.0000	0.0000	2.9453	0.3583	10.8%	1.9%
Extended detention S		15.0768		1.6013			0.0000	0.0000	13.4754	1.6014	10.6%	8.4%
Total		18.9972		2.2874			0.0000	0.0013	16.7090	2.2868		12.0%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.5405	0.5405	0.0131	0.5274	0.0000	0.0000	0.0000	0.0000	0.2759	51.0%	0.9%
	Underdrain		0.5274	0.2628		0.2634	0.0000	0.0011	0.2634			
Bioswale S	Swale + Media	0.4352	0.4352	0.0102	0.4250	0.0000	0.0000	0.0000	0.0000	0.2245	51.6%	0.7%
	Underdrain		0.4250	0.2143		0.2098	0.0000	0.0009	0.2098			
Extended detention N		5.2256		0.5168			0.0000	0.0000	4.7088	0.5168	9.9%	1.7%
Extended detention S		23.8488		2.3041			0.0000	0.0001	21.5445	2.3042	9.7%	7.7%
Total		30.0500		3.3212			0.0000	0.0022	26.7265	3.3213		11.1%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.2283	0.2283	0.0006	0.2277	0.0000	0.0000	0.0000	0.0000	0.1075	47.1%	0.8%
	Underdrain		0.2277	0.1069		0.1194	0.0000	0.0014	0.1194			
Bioswale S	Swale + Media	0.1838	0.1838	0.0005	0.1834	0.0000	0.0000	0.0000	0.0000	0.0877	47.7%	0.7%
	Underdrain		0.1834	0.0873		0.0950	0.0000	0.0011	0.0950			
Extended detention N		2.2074		0.4843			0.0000	0.0000	1.7230	0.4843	21.9%	3.8%
Extended detention S		10.0740		2.1463			0.0000	0.0001	7.9276	2.1463	21.3%	16.9%
Total		12.6934		2.8259			0.0000	0.0025	9.8650	2.8259		22.3%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.0902	0.0902	0.0002	0.0900	0.0000	0.0000	0.0000	0.0000	0.0424	47.0%	0.8%
	Underdrain		0.0900	0.0422		0.0472	0.0000	0.0005	0.0472			
Bioswale S	Swale + Media	0.0726	0.0726	0.0002	0.0724	0.0000	0.0000	0.0000	0.0000	0.0346	47.7%	0.7%
	Underdrain		0.0724	0.0344		0.0376	0.0000	0.0004	0.0376			
Extended detention N		0.8721		0.1907			0.0000	0.0000	0.6814	0.1907	21.9%	3.8%
Extended detention S		3.9801		0.8453			0.0000	0.0000	3.1348	0.8453	21.2%	16.9%
Total		5.0151		1.1131			0.0000	0.0010	3.9010	1.1131		22.2%

Table E-10 2010 Flows and Loads of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underdrain (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3986	0.3986	0.0006	0.3979	0.0000	0.0000	0.0000	0.0000	0.0940	22.9%	0.4%
	Underdrain		0.3979	0.0934		0.3164	0.0118	0.0000	0.3164			
Bioswale S	Swale + Media	0.3209	0.3209	0.0005	0.3204	0.0000	0.0000	0.0000	0.0000	0.0773	23.4%	0.3%
	Underdrain		0.3204	0.0768		0.2534	0.0098	0.0000	0.2534			
Extended detention N		3.8536		0.0218			0.0000	0.0000	3.8318	0.0218	0.6%	0.1%
Extended detention S		17.5872		0.0863			0.0000	0.0000	17.5009	0.0862	0.5%	0.4%
Total		22.1603		0.2794			0.0216	0.0000	21.9025	0.2794		1.3%

Annual rainfall (in)	31.874
drainage area (ac)	20.02
overall runoff coeff	0.417

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underdrain (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	190,791	190,791	1,635	189,156	0	0	0	0	119,004	62.3%	1.1%
	Underdrain		189,156	117,376		71,959	172	0	71,959			
Bioswale S	Swale + Media	153,625	153,625	1,239	152,386	0	0	0	0	96,745	62.9%	0.9%
	Underdrain		152,386	95,512		57,018	138	0	57,018			
Extended detention N		1,844,774		645,137			7	0	1,199,644	645,138	35.0%	6.1%
Extended detention S		8,419,217		2,867,181			32	0	5,552,068	2,867,181	34.1%	27.0%
Total		10,608,407		3,728,079			349	0	6,880,688	3,728,068		35.1%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.7505	0.7505	0.0006	0.7498	0.0000	0.0000	0.0000	0.0000	0.3818	50.5%	0.9%
	Underdrain		0.7498	0.3812		0.3737	0.0050	0.0000	0.3737			
Bioswale S	Swale + Media	0.6042	0.6042	0.0005	0.6038	0.0000	0.0000	0.0000	0.0000	0.3112	51.2%	0.7%
	Underdrain		0.6038	0.3108		0.2970	0.0040	0.0000	0.2970			
Extended detention N		7.2561		0.0599			0.0000	0.0000	7.1963	0.0599	0.8%	0.1%
Extended detention S		33.1156		0.2638			0.0002	0.0000	32.8520	0.2638	0.8%	0.6%
Total		41.7264		1.0168			0.0093	0.0000	40.7189	1.0168		2.4%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3675	0.3675	0.0069	0.3606	0.0000	0.0000	0.0000	0.0000	0.1951	53.0%	1.0%
	Underdrain		0.3606	0.1882		0.1727	0.0004	0.0000	0.1727			
Bioswale S	Swale + Media	0.2959	0.2959	0.0052	0.2907	0.0000	0.0000	0.0000	0.0000	0.1593	53.7%	0.8%
	Underdrain		0.2907	0.1535		0.1375	0.0009	0.0000	0.1375			
Extended detention N		3.5530		0.4263			0.0000	0.0000	3.1266	0.4263	12.0%	2.1%
Extended detention S		16.2150		1.9109			0.0000	0.0000	14.3042	1.9109	11.8%	9.4%
Total		20.4313		2.6910			0.0013	0.0000	17.7410	2.6916		13.2%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.5821	0.5821	0.0059	0.5762	0.0000	0.0000	0.0000	0.0000	0.3188	54.6%	1.0%
	Underdrain		0.5762	0.3128		0.2645	0.0011	0.0000	0.2645			
Bioswale S	Swale + Media	0.4687	0.4687	0.0045	0.4643	0.0000	0.0000	0.0000	0.0000	0.2594	55.2%	0.8%
	Underdrain		0.4643	0.2549		0.2103	0.0009	0.0000	0.2103			
Extended detention N		5.6287		0.6106			0.0000	0.0000	5.0182	0.6105	10.8%	1.9%
Extended detention S		25.6882		2.7206			0.0001	0.0000	22.9677	2.7206	10.6%	8.4%
Total		32.3678		3.9094			0.0022	0.0000	28.4607	3.9093		12.1%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.2370	0.2370	0.0003	0.2368	0.0000	0.0000	0.0000	0.0000	0.1236	51.9%	0.9%
	Underdrain		0.2368	0.1234		0.1147	0.0014	0.0000	0.1147			
Bioswale S	Swale + Media	0.1908	0.1908	0.0002	0.1906	0.0000	0.0000	0.0000	0.0000	0.1008	52.5%	0.8%
	Underdrain		0.1906	0.1006		0.0912	0.0011	0.0000	0.0912			
Extended detention N		2.2917		0.5679			0.0000	0.0000	1.7238	0.5679	24.8%	4.3%
Extended detention S		10.4587		2.5140			0.0001	0.0000	7.9448	2.5140	24.0%	19.1%
Total		13.1782		3.3063			0.0025	0.0000	9.8744	3.3063		25.1%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.0937	0.0937	0.0001	0.0936	0.0000	0.0000	0.0000	0.0000	0.0489	51.9%	0.9%
	Underdrain		0.0936	0.0488		0.0453	0.0005	0.0000	0.0453			
Bioswale S	Swale + Media	0.0755	0.0755	0.0001	0.0754	0.0000	0.0000	0.0000	0.0000	0.0399	52.5%	0.8%
	Underdrain		0.0754	0.0398		0.0360	0.0004	0.0000	0.0360			
Extended detention N		0.9061		0.2241			0.0000	0.0000	0.6820	0.2241	24.7%	4.3%
Extended detention S		4.1352		0.9920			0.0000	0.0000	3.1432	0.9920	24.0%	19.0%
Total		5.2104		1.3049			0.0010	0.0000	3.9065	1.3049		25.0%

Table E-11 2007-2010 Flows and Loads of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underdrain (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	1.4365	1.4365	0.0030	1.4157	0.0178	0.0000	0.0000	0.0178	0.3208	22.3%	0.4%
	Underdrain		1.4157	0.3178		1.0979	0.0000	0.0000	1.0979			
Bioswale S	Swale + Media	1.1566	1.1566	0.0024	1.1415	0.0127	0.0000	0.0000	0.0127	0.2635	22.8%	0.3%
	Underdrain		1.1415	0.2611		0.8805	0.0000	0.0000	0.8805			
Extended detention N		13.8895		0.0839			0.0000	0.0000	13.8057	0.0839	0.6%	0.1%
Extended detention S		63.3889		0.3290			0.0000	0.0000	63.0600	0.3289	0.5%	0.4%
Total		79.8716		0.9971			0.0000	0.0000	78.8746	0.9971		1.2%

total rainfall (in)	121.304
drainage area (ac)	20.02
overall runoff coeff	0.395

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underdrain (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	732,665	732,665	9,560	721,785	1,320	0	0	1,320	461,671	63.0%	1.1%
	Underdrain		721,786	452,111		269,674	0	0	269,674			
Bioswale S	Swale + Media	589,939	589,939	7,172	581,791	976	0	0	976	374,124	63.4%	0.9%
	Underdrain		581,791	366,951		214,840	0	0	214,840			
Extended detention N		7,084,193		2,179,804			0	0	4,904,385	2,179,809	30.8%	5.4%
Extended detention S		32,330,960		9,663,062			0	0	22,667,903	9,663,058	29.9%	23.7%
Total		40,737,758		12,678,659			0	0	28,059,097	12,678,661		31.1%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	2.9835	2.9835	0.0049	2.9748	0.0037	0.0000	0.0000	0.0037	1.4800	49.6%	0.9%
	Underdrain		2.9748	1.4751		1.4997	0.0000	0.0000	1.4997			
Bioswale S	Swale + Media	2.4022	2.4022	0.0036	2.3959	0.0027	0.0000	0.0000	0.0027	1.2080	50.3%	0.7%
	Underdrain		2.3959	1.2044		1.1915	0.0000	0.0000	1.1915			
Extended detention N		28.8471		0.1900			0.0000	0.0000	28.6571	0.1900	0.7%	0.1%
Extended detention S		131.6519		0.8321			0.0000	0.0000	130.8198	0.8321	0.6%	0.5%
Total		165.8847		3.7102			0.0000	0.0000	162.1745	3.7102		2.2%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	1.3970	1.3970	0.0441	1.3411	0.0119	0.0000	0.0000	0.0119	0.7867	56.3%	1.0%
	Underdrain		1.3411	0.7427		0.5984	0.0000	0.0000	0.5984			
Bioswale S	Swale + Media	1.1248	1.1248	0.0343	1.0822	0.0083	0.0000	0.0000	0.0083	0.6387	56.8%	0.8%
	Underdrain		1.0822	0.6044		0.4778	0.0000	0.0000	0.4778			
Extended detention N		13.5076		1.3082			0.0000	0.0000	12.1995	1.3082	9.7%	1.7%
Extended detention S		61.6460		5.8222			0.0000	0.0000	55.8239	5.8221	9.4%	7.5%
Total		77.6755		8.5558			0.0000	0.0000	69.1198	8.5558		11.0%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	2.2419	2.2419	0.0385	2.1915	0.0118	0.0000	0.0000	0.0118	1.2491	55.7%	1.0%
	Underdrain		2.1915	1.2105		0.9810	0.0000	0.0000	0.9810			
Bioswale S	Swale + Media	1.8051	1.8051	0.0297	1.7671	0.0083	0.0000	0.0000	0.0083	1.0148	56.2%	0.8%
	Underdrain		1.7671	0.9851		0.7820	0.0000	0.0000	0.7820			
Extended detention N		21.6768		1.9315			0.0000	0.0000	19.7453	1.9315	8.9%	1.5%
Extended detention S		98.9285		8.5594			0.0000	0.0000	90.3690	8.5595	8.7%	6.9%
Total		124.6523		12.7548			0.0000	0.0000	111.8974	12.7548		10.2%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.9483	0.9483	0.0019	0.9453	0.0011	0.0000	0.0000	0.0011	0.4806	50.7%	0.9%
	Underdrain		0.9453	0.4788		0.4665	0.0000	0.0000	0.4665			
Bioswale S	Swale + Media	0.7635	0.7635	0.0014	0.7613	0.0008	0.0000	0.0000	0.0008	0.3919	51.3%	0.7%
	Underdrain		0.7613	0.3906		0.3708	0.0000	0.0000	0.3708			
Extended detention N		9.1688		1.9367			0.0000	0.0000	7.2321	1.9367	21.1%	3.7%
Extended detention S		41.8446		8.5485			0.0000	0.0000	33.2961	8.5485	20.4%	16.2%
Total		52.7252		11.3577			0.0000	0.0000	41.3675	11.3577		21.5%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underdrain (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale N	Swale + Media	0.3787	0.3787	0.0009	0.3770	0.0009	0.0000	0.0000	0.0009	0.1924	50.8%	0.9%
	Underdrain		0.3770	0.1915		0.1855	0.0000	0.0000	0.1855			
Bioswale S	Swale + Media	0.3049	0.3049	0.0006	0.3036	0.0006	0.0000	0.0000	0.0006	0.1569	51.5%	0.7%
	Underdrain		0.3036	0.1563		0.1474	0.0000	0.0000	0.1474			
Extended detention N		3.6617		0.7718			0.0000	0.0000	2.8898	0.7718	21.1%	3.7%
Extended detention S		16.7111		3.4066			0.0000	0.0000	13.3045	3.4066	20.4%	16.2%
Total		21.0564		4.5277			0.0000	0.0000	16.5287	4.5277		21.5%

Table E-12 Summary of Flow and Load Removed of Subbasin 70 BMP Performance Evaluation Modeling

FLOW

BMP	Flow removed (ac-ft)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.0972	0.0658	0.0638	0.0940	0.3208	16.9%	58.3%	18.2%	22.9%	22.3%	0.3%	1.0%	0.3%	0.4%	0.4%
Bioswale S	0.0799	0.0540	0.0523	0.0773	0.2635	17.3%	59.4%	18.5%	23.4%	22.8%	0.3%	0.9%	0.3%	0.3%	0.3%
Extended detention N	0.0361	0.0082	0.0177	0.0218	0.0839	0.6%	0.8%	0.5%	0.6%	0.6%	0.1%	0.1%	0.1%	0.1%	0.1%
Extended detention S	0.1413	0.0327	0.0687	0.0862	0.3289	0.6%	0.7%	0.4%	0.5%	0.5%	0.4%	0.5%	0.4%	0.4%	0.4%
Total	0.3544	0.1608	0.2025	0.2794	0.9971						1.1%	2.6%	1.0%	1.3%	1.2%

BACT

BMP	Load removed (10^6)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	159,644	81,152	101,870	119,004	461,671	60.5%	80.2%	57.6%	62.3%	63.0%	1.1%	1.4%	1.0%	1.1%	1.1%
Bioswale S	129,538	65,044	82,796	96,745	374,124	61.0%	79.8%	58.1%	62.9%	63.4%	0.9%	1.2%	0.8%	0.9%	0.9%
Extended detention N	750,333	227,777	556,562	645,138	2,179,809	29.4%	23.3%	32.5%	35.0%	30.8%	5.1%	4.0%	5.7%	6.1%	5.4%
Extended detention S	3,324,642	993,104	2,478,130	2,867,181	9,663,058	28.6%	22.2%	31.8%	34.1%	29.9%	22.7%	17.6%	25.2%	27.0%	23.7%
Total	4,364,157	1,367,078	3,219,358	3,728,068	12,678,661						29.8%	24.3%	32.7%	35.1%	31.1%

ORGN

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.4765	0.2918	0.3299	0.3818	1.4800	43.8%	68.4%	45.9%	50.5%	49.6%	0.8%	1.2%	0.8%	0.9%	0.9%
Bioswale S	0.3899	0.2375	0.2694	0.3112	1.2080	44.5%	69.2%	46.5%	51.2%	50.3%	0.6%	1.0%	0.7%	0.7%	0.7%
Extended detention N	0.0625	0.0177	0.0498	0.0599	0.1900	0.6%	0.4%	0.7%	0.8%	0.7%	0.1%	0.1%	0.1%	0.1%	0.1%
Extended detention S	0.2728	0.0759	0.2197	0.2638	0.8321	0.6%	0.4%	0.7%	0.8%	0.6%	0.5%	0.3%	0.5%	0.6%	0.5%
Total	1.2017	0.6228	0.8688	1.0168	3.7102						2.0%	2.6%	2.2%	2.4%	2.2%

NH3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.2879	0.1229	0.1809	0.1951	0.7867	54.0%	79.6%	52.9%	53.0%	56.3%	1.0%	1.4%	1.0%	1.0%	1.0%
Bioswale S	0.2342	0.0989	0.1463	0.1593	0.6387	54.5%	79.6%	53.2%	53.7%	56.8%	0.8%	1.2%	0.8%	0.8%	0.8%
Extended detention N	0.4454	0.0781	0.3583	0.4263	1.3082	8.6%	5.2%	10.8%	12.0%	9.7%	1.5%	0.9%	1.9%	2.1%	1.7%
Extended detention S	1.9740	0.3359	1.6014	1.9109	5.8221	8.4%	4.9%	10.6%	11.8%	9.4%	6.7%	3.9%	8.4%	9.4%	7.5%
Total	2.9416	0.6358	2.2868	2.6916	8.5558						9.9%	7.4%	12.0%	13.2%	11.0%

NO3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.4444	0.2101	0.2759	0.3188	1.2491	52.6%	76.6%	51.0%	54.6%	55.7%	0.9%	1.4%	0.9%	1.0%	1.0%
Bioswale S	0.3618	0.1692	0.2245	0.2594	1.0148	53.2%	76.6%	51.6%	55.2%	56.2%	0.8%	1.1%	0.7%	0.8%	0.8%
Extended detention N	0.6669	0.1373	0.5168	0.6105	1.9315	8.2%	5.2%	9.9%	10.8%	8.9%	1.4%	0.9%	1.7%	1.9%	1.5%
Extended detention S	2.9438	0.5908	2.3042	2.7206	8.5595	7.9%	4.9%	9.7%	10.6%	8.7%	6.3%	3.9%	7.7%	8.4%	6.9%
Total	4.4169	1.1073	3.3213	3.9093	12.7548						9.4%	7.3%	11.1%	12.1%	10.2%

ORGP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.1567	0.0927	0.1075	0.1236	0.4806	44.9%	69.1%	47.1%	51.9%	50.7%	0.8%	1.2%	0.8%	0.9%	0.9%
Bioswale S	0.1281	0.0754	0.0877	0.1008	0.3919	45.6%	69.8%	47.7%	52.5%	51.3%	0.7%	1.0%	0.7%	0.8%	0.7%
Extended detention N	0.6786	0.2058	0.4843	0.5679	1.9367	20.1%	15.9%	21.9%	24.8%	21.1%	3.5%	2.8%	3.8%	4.3%	3.7%
Extended detention S	2.9928	0.8954	2.1463	2.5140	8.5485	19.4%	15.1%	21.3%	24.0%	20.4%	15.4%	12.0%	16.9%	19.1%	16.2%
Total	3.9561	1.2693	2.8259	3.3063	11.3577						20.4%	17.0%	22.3%	25.1%	21.5%

ORTHOP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale N	0.0644	0.0367	0.0424	0.0489	0.1924	45.4%	69.2%	47.0%	51.9%	50.8%	0.8%	1.2%	0.8%	0.9%	0.9%
Bioswale S	0.0526	0.0298	0.0346	0.0399	0.1569	46.1%	69.9%	47.7%	52.5%	51.5%	0.7%	1.0%	0.7%	0.8%	0.7%
Extended detention N	0.2756	0.0814	0.1907	0.2241	0.7718	20.1%	15.9%	21.9%	24.7%	21.1%	3.5%	2.8%	3.8%	4.3%	3.7%
Extended detention S	1.2153	0.3539	0.8453	0.9920	3.4066	19.4%	15.1%	21.2%	24.0%	20.4%	15.4%	12.0%	16.9%	19.0%	16.2%
Total	1.6078	0.5018	1.1131	1.3049	4.5277						20.4%	17.0%	22.2%	25.0%	21.5%

F. Subbasin 150 BMP Performance Evaluation Modeling

Site Description and Land Uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 150 is in the open area at the intersection of Larchmont Dr and Greenwich Blvd as shown in Exhibit F-1. The drainage area to the BMP site was delineated using ArcHydro and the DEM provided by the River Authority and determined to be 9.425 acres. As shown in Exhibit F-1, the land use in the delineated drainage area includes mostly single-family residential and some transportation. The land uses and their corresponding impervious cover percentages from the 2017 land use data provided by the River Authority are used to determine the pervious and impervious areas within the delineated area, as listed in Table F-1.

Table F-1 Land Uses of Subbasin 150 BMP Site

Land use	IC%	Pervious Area (ac)	Impervious Area (ac)	Total Area (ac)
Residential Low Density	25	0.425	0.141	0.566
Residential High Density	65	2.272	4.220	6.492
Transportation	90	0.237	2.130	2.367
TOTAL	68.9	2.934	6.491	9.425

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQV for the selected BMP site is:
1.5”/12 x 0.6 x 6.491 ac x 1.2 = 0.584 ac-ft

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority’s LID Manual (SARA, 2019; page B-117).

Following evaluation of site conditions and discussion with the River Authority, a bioretention was proposed at this site and the layout is shown in Exhibit F-2. The BMP footprint is located to avoid large trees and existing facilities in the area. Based on size classification in the BMP Tool Database, this bioretention is considered “large.” The WQV and surface area of the bioretention are shown in Table F-2.

Table F-2 Water Quality Volume and Surface Area of Subbasin 150 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioretention	0.6069	0.2748
Required	0.5840	

Note: Surface area is the area at the water level of the WQV.

Exhibit F-1 Delineated Drainage Area to Subbasin 150 BMP Site

Exhibit F-2 Proposed BMP Layout on Subbasin 150 Site

Modeling Bioretention in HSPF

A bioretention pond is set up in HSPF similar to a bioswale as shown in Exhibit D-1. The bioretention includes two components each represented by a HSPF RCHRES. The upper component includes the vegetation area and soil media. The lower component is an underdrain layer. Stormwater runoff entering a bioretention will flow through the soil media into an underdrain layer. Higher flow would overflow the bioretention. Based on the SSURGO database, the soil at this BMP site is classified as hydrologic soil group (HSG) D, which has a very low infiltration capacity. As a result, no infiltration is assumed to enter the soil below the underdrain layer. When the underdrain layer is full, treated runoff would leave the underdrain and outflow downstream. The total outflow is the sum of the overflow from the vegetation area and soil media and the outflow from the underdrain layer. Using data listed in Table B-2-1 of the River Authority's LID Manual, the soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table F-3 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Table F-3 EC Concentrations of Subbasin 150 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioretention	71,623	15,065	13,389	14,848

Tables F-4 to F-7 list the model output annual inflows and outflows of the bioretention in Subbasin 150 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed and the corresponding removal percentages (or BMP performance) are also listed. Table F-8 shows the same set of information but for the 4-year total. The loads removed and removal percentages calculated are summarized in Table F-9 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

Table F-4 2007 Flows and Loads of Subbasin 150 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	17.3603	17.3603	0.0570	13.7039	3.5994	0.0000	0.0000	16.1724	1.1559	6.7%
	Underdrain		13.7039	1.0989		12.5730	0.0000	0.0320			

total rainfall (in)	47.927
drainage area (ac)	9.425
overall runoff coeff	0.461

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	7,456,312	7,456,312	884,338	5,692,313	879,672	0	0	4,040,012	3,416,300	45.8%
	Underdrain		5,692,313	2,531,971		3,160,339	0	0			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	30.6679	30.6679	0.6611	27.0851	2.9219	0.0000	0.0000	22.1780	8.4888	27.7%
	Underdrain		27.0851	7.8279		19.2562	0.0000	0.0010			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	15.3304	15.3304	2.8775	9.9835	2.4695	0.0000	0.0000	7.6877	7.6427	49.9%
	Underdrain		9.9835	4.7653		5.2182	0.0000	0.0000			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	24.2608	24.2608	3.4970	17.2433	3.5204	0.0000	0.0000	13.0339	11.2269	46.3%
	Underdrain		17.2433	7.7298		9.5135	0.0000	0.0000			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	9.8741	9.8741	0.9869	8.0429	0.8442	0.0000	0.0000	5.1725	4.7016	47.6%
	Underdrain		8.0429	3.7146		4.3283	0.0000	0.0000			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	4.0194	4.0194	0.4100	3.2529	0.3565	0.0000	0.0000	2.1175	1.9019	47.3%
	Underdrain		3.2529	1.4919		1.7611	0.0000	0.0000			

Table F-5 2008 Flows and Loads of Subbasin 150 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	3.6617	3.6617	0.0095	3.5437	0.1085	0.0000	0.0000	2.8996	0.7942	21.5%
	Underdrain		3.5437	0.7847		2.7911	0.0320	0.0000			

total rainfall (in)	14.221
drainage area (ac)	9.425
overall runoff coeff	0.328

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	2,608,504	2,608,504	206,117	2,343,044	59,335	0	0	1,166,692	1,441,812	55.3%
	Underdrain		2,343,044	1,235,686		1,107,356	0	0			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	10.8691	10.8691	0.1390	10.5305	0.1996	0.0000	0.0000	6.5964	4.2738	39.3%
	Underdrain		10.5305	4.1348		6.3968	0.0010	0.0000			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	4.1530	4.1530	0.5350	3.5385	0.0795	0.0000	0.0000	1.6896	2.4634	59.3%
	Underdrain		3.5385	1.9284		1.6101	0.0000	0.0000			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	7.4485	7.4485	0.6943	6.5952	0.1589	0.0000	0.0000	3.2332	4.2152	56.6%
	Underdrain		6.5952	3.5209		3.0743	0.0000	0.0000			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	3.4117	3.4117	0.2196	3.1316	0.0606	0.0000	0.0000	1.4644	1.9473	57.1%
	Underdrain		3.1316	1.7277		1.4039	0.0000	0.0000			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	1.3505	1.3505	0.0859	1.2408	0.0239	0.0000	0.0000	0.5780	0.7726	57.2%
	Underdrain		1.2408	0.6867		0.5541	0.0000	0.0000			

Table F-6 2009 Flows and Loads of Subbasin 150 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	10.8434	10.8434	0.0275	8.4555	2.3605	0.0000	0.0000	9.9275	0.7671	7.1%
	Underdrain		8.4555	0.7398		7.5669	0.0000	0.1488			

total rainfall (in)	31.205
drainage area (ac)	9.425
overall runoff coeff	0.442

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	4,999,873	4,999,873	682,932	4,029,173	287,767	0	0	2,532,057	2,458,906	49.2%
	Underdrain		4,029,173	1,775,563		2,244,290	0	8,910			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	20.2111	20.2111	0.4694	18.9076	0.8341	0.0000	0.0000	13.3830	6.4336	31.8%
	Underdrain		18.9076	5.9611		12.5489	0.0000	0.3944			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	9.6925	9.6925	2.0049	6.1024	1.5853	0.0000	0.0000	4.7990	4.8904	50.5%
	Underdrain		6.1024	2.8853		3.2137	0.0000	0.0032			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	15.7922	15.7922	2.4462	11.4914	1.8546	0.0000	0.0000	8.1685	7.6068	48.2%
	Underdrain		11.4914	5.1596		6.3140	0.0000	0.0169			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	6.4207	6.4207	0.7009	5.4830	0.2368	0.0000	0.0000	3.1581	3.2471	50.6%
	Underdrain		5.4830	2.5455		2.9213	0.0000	0.0155			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.5550	2.5550	0.2784	2.1728	0.1038	0.0000	0.0000	1.2614	1.2874	50.4%
	Underdrain		2.1728	1.0087		1.1576	0.0000	0.0062			

Table F-7 2010 Flows and Loads of Subbasin 150 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	14.5471	14.5471	0.0440	10.5707	3.9323	0.0000	0.0000	13.5718	1.0730	7.3%
	Underdrain		10.5707	1.0289		9.6395	0.1488	0.0511			

total rainfall (in)	37.961
drainage area (ac)	9.425
overall runoff coeff	0.488

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	5,731,255	5,731,255	958,315	3,861,535	911,399	0	0	3,176,780	2,559,532	44.6%
	Underdrain		3,861,535	1,601,445		2,265,381	8,910	3,853			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	21.7682	21.7682	0.6971	18.0343	3.0368	0.0000	0.0000	15.9340	5.8631	26.5%
	Underdrain		18.0343	5.1662		12.8972	0.3944	0.3655			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	11.5825	11.5825	2.7742	6.0990	2.7093	0.0000	0.0000	6.0311	5.5537	47.9%
	Underdrain		6.0990	2.7797		3.3218	0.0032	0.0009			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	18.0012	18.0012	3.4398	11.1173	3.4441	0.0000	0.0000	9.8346	8.1768	45.4%
	Underdrain		11.1173	4.7375		6.3905	0.0169	0.0067			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	6.9072	6.9072	0.9672	5.0864	0.8537	0.0000	0.0000	3.6678	3.2475	46.9%
	Underdrain		5.0864	2.2807		2.8141	0.0155	0.0073			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.7523	2.7523	0.3875	2.0141	0.3507	0.0000	0.0000	1.4663	1.2892	46.7%
	Underdrain		2.0141	0.9019		1.1156	0.0062	0.0029			

Table F-8 2007-2010 Flows and Loads of Subbasin 150 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	46.4126	46.4126	0.1380	36.2738	10.0007	0.0000	0.0000	42.5713	3.7902	8.2%
	Underdrain		36.2738	3.6522		32.5706	0.0000	0.0511			

total rainfall (in)	131.314
drainage area (ac)	9.425
overall runoff coeff	0.450

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	20,795,944	20,795,944	2,731,702	15,926,065	2,138,174	0	0	10,915,540	9,876,551	47.5%
	Underdrain		15,926,065	7,144,665		8,777,366	0	3,853			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	83.5163	83.5163	1.9665	74.5575	6.9924	0.0000	0.0000	58.0914	25.0594	30.0%
	Underdrain		74.5576	23.0900		51.0990	0.0000	0.3655			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	40.7583	40.7583	8.1915	25.7234	6.8434	0.0000	0.0000	20.2073	20.5502	50.4%
	Underdrain		25.7234	12.3586		13.3638	0.0000	0.0009			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	65.5026	65.5026	10.0773	46.4472	8.9779	0.0000	0.0000	34.2702	31.2257	47.7%
	Underdrain		46.4472	21.1478		25.2923	0.0000	0.0067			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	26.6137	26.6137	2.8746	21.7438	1.9952	0.0000	0.0000	13.4629	13.1435	49.4%
	Underdrain		21.7438	10.2685		11.4676	0.0000	0.0073			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	10.6773	10.6773	1.1618	8.6806	0.8349	0.0000	0.0000	5.4233	5.2511	49.2%
	Underdrain		8.6806	4.0892		4.5884	0.0000	0.0029			

Table F-9 Summary of Flow and Load Removed of Subbasin 150 BMP Performance Evaluation Modeling

Constituent	Flow/Load removed (ac-ft)					% removed				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Flow	1.1559	0.7942	0.7671	1.0730	3.7902	6.7%	21.5%	7.1%	7.3%	8.2%
BACT	3,416,300	1,441,812	2,458,906	2,559,532	9,876,551	45.8%	55.3%	49.2%	44.6%	47.5%
ORGN	8.4888	4.2738	6.4336	5.8631	25.0594	27.7%	39.3%	31.8%	26.5%	30.0%
NH3N	7.6427	2.4634	4.8904	5.5537	20.5502	49.9%	59.3%	50.5%	47.9%	50.4%
NO3N	11.2269	4.2152	7.6068	8.1768	31.2257	46.3%	56.6%	48.2%	45.4%	47.7%
ORGP	4.7016	1.9473	3.2471	3.2475	13.1435	47.6%	57.1%	50.6%	46.9%	49.4%
ORTHOP	1.9019	0.7726	1.2874	1.2892	5.2511	47.3%	57.2%	50.4%	46.7%	49.2%

G. Subbasin 260 BMP Performance Evaluation Modeling

Site Description and Land uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 260 is Monterrey Park bounded by Fortuna St to the north and W. Commerce St to the south as shown in Exhibit G-1. Zarzamora Creek is on the east side of the park. Existing facilities in the park include soccer fields, tennis courts, and baseball fields.

Following evaluation of site conditions including floodplain boundary and discussion with the River Authority, a bioretention was proposed at the north end of the park (Bioretention N) and another at the south end (Bioretention S) as shown in Exhibits G-1 and G-2. Bioretention S is located in two open areas of the parking lot. The two areas were modeled as one bioretention in the model. Based on the size classification in the BMP Tool Database, Bioretention N was considered "average" while Bioretention S was considered "large."

The drainage area to each bioretention was delineated using Arc Hydro and the DEM data provided by the River Authority. The areas were determined to be 5.442 acres for Bioretention N and 21.784 acres for Bioretention S. As shown in Exhibit G-1, the land use in the delineated drainage area includes mostly single-family residential, some transportation, and some commercial.

The land uses and their corresponding impervious cover percentages from the 2017 land use data provided by the River Authority were used to determine the pervious (Per.) and impervious (Imp.) areas within the delineated drainage areas, as listed in Table G-1.

Table G-1 Land uses of Subbasin 260 BMP Sites

Land use	IC%	Bioretention N			IC%	Bioretention S		
		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)
Residential Medium Density	38	2.396	1.468	3.864	38	6.625	4.061	10.686
Commercial	90	0.067	0.600	0.667	90	0.712	6.409	7.121
Transportation	90	0.091	0.820	0.911	90	0.397	3.580	3.977
TOTAL	53.1	2.554	2.888	5.442	64.5	7.734	14.050	21.784

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQVs for the selected BMP sites are:
1.5"/12 x 0.6 x 2.888 ac x 1.2 = 0.260 ac-ft for Bioretention N
1.5"/12 x 0.6 x 14.05 ac x 1.2 = 1.264 ac-ft for Bioretention S

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority's LID Manual (SARA, 2019; page B-117). The water quality volume and surface area of each BMP are shown in Table G-2.

Table G-2 Water Quality Volume and Surface Area of Subbasin 260 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioretention N	0.2850	0.1328
Bioretention S	1.3969	0.6342
Total	1.6819	
Required	1.5240	

Note: Surface area is the area at the water level of the WQV.

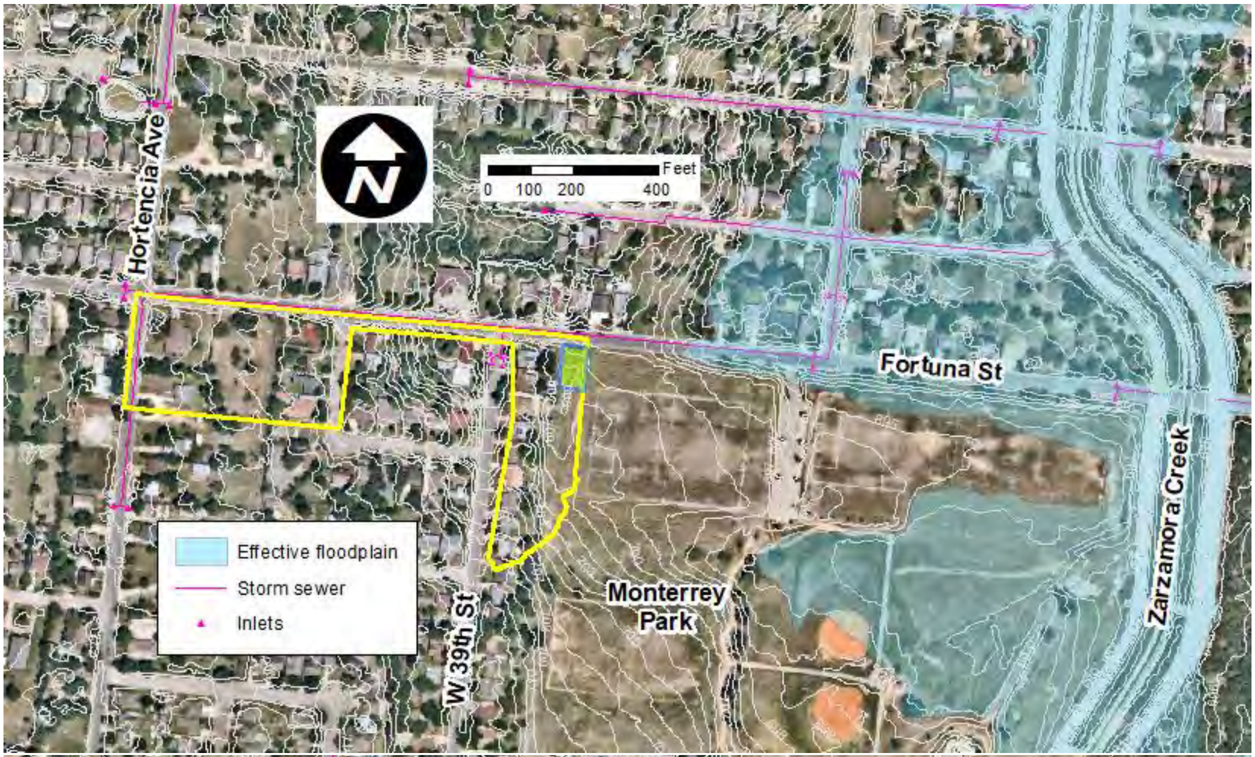


Exhibit G-1 Delineated Drainage Area to Subbasin 260 BMP Site

Exhibit G-2 Proposed BMP Layout on Subbasin 260 Site

Modeling Bioretention in HSPF

Refer to the discussion in Section F.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table G-3 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Table G-3 EC Concentrations of Subbasin 260 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioretention N	64,743	14,316	12,120	13,678
Bioretention S	55,429	11,945	10,434	11,542
Overall	57,020	12,355	10,611	11,908

Tables G-4 to G-7 list the model output annual inflows and outflows of the bioretention in Subbasin 150 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed and the corresponding removal percentages (or BMP performance) are also listed. Table G-8 shows the same set of information but for the 4-year total.

The constituent removal percentages were calculated in two approach – based on individual input to a BMP and based on the total input coming from the total drainage area. The loads removed and removal percentages calculated are summarized in Table G-9 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

The differences in the removal percentages based on individual input to a BMP for some of the nutrients are due to different decay coefficients for average and large bioretention from the BMP Tool Database.

Table G-4 2007 Flows and Loads of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	7.7448	7.7448	0.0257	6.2048	1.5144	0.0000	0.0000	7.1938	0.5389	7.0%	1.2%
	Underdrain		6.2048	0.5132		5.6794	0.0000	0.0121				
Bioretention S	Pond + Media	37.5925	37.5925	0.1258	30.2527	7.2138	0.0000	0.0000	34.8824	2.6541	7.1%	5.9%
	Underdrain		30.2527	2.5281		27.6686	0.0000	0.0561				
Total		45.3374		3.1929			0.0000	0.0682	42.0762	3.1930		7.0%

total rainfall (in)	47.927
drainage area (ac)	27.228
overall runoff coeff	0.417

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3,026,753	3,026,753	358,878	2,336,001	331,868	0	0	1,618,106	1,408,647	46.5%	9.1%
	Underdrain		2,336,001	1,049,763		1,286,238	0	0				
Bioretention S	Pond + Media	12,505,333	12,505,333	1,473,190	9,715,906	1,316,258	0	0	6,644,967	5,860,367	46.9%	37.7%
	Underdrain		9,715,906	4,387,209		5,328,709	0	0				
Total		15,532,086		7,269,040			0	0	8,263,073	7,269,013		46.8%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	13.8526	13.8526	0.2964	12.3187	1.2376	0.0000	0.0000	9.9379	3.9135	28.3%	4.9%
	Underdrain		12.3187	3.6171		8.7003	0.0000	0.0013				
Bioretention S	Pond + Media	66.8137	66.8137	1.4090	59.7530	5.6517	0.0000	0.0000	47.7132	19.0926	28.6%	23.7%
	Underdrain		59.7530	17.6836		42.0616	0.0000	0.0079				
Total		80.6664		23.0060			0.0000	0.0092	57.6511	23.0061		28.5%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.8778	6.8778	0.7640	5.0125	1.1014	0.0000	0.0000	4.1600	2.7178	39.5%	6.7%
	Underdrain		5.0125	1.9538		3.0586	0.0000	0.0000				
Bioretention S	Pond + Media	33.4247	33.4247	6.1845	22.3587	4.8815	0.0000	0.0000	16.4115	17.0132	50.9%	42.2%
	Underdrain		22.3587	10.8287		11.5300	0.0000	0.0000				
Total		40.3025		19.7310			0.0000	0.0000	20.5715	19.7310		49.0%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	10.8572	10.8572	0.8907	8.4343	1.5322	0.0000	0.0000	6.8348	4.0224	37.0%	6.3%
	Underdrain		8.4343	3.1318		5.3026	0.0000	0.0000				
Bioretention S	Pond + Media	52.8264	52.8264	7.5314	38.4149	6.8800	0.0000	0.0000	27.8122	25.0142	47.4%	39.3%
	Underdrain		38.4149	17.4827		20.9322	0.0000	0.0000				
Total		63.6837		29.0366			0.0000	0.0000	34.6470	29.0367		45.6%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.4377	4.4377	0.1081	3.9450	0.3846	0.0000	0.0000	3.1204	1.3173	29.7%	5.1%
	Underdrain		3.9450	1.2090		2.7358	0.0000	0.0000				
Bioretention S	Pond + Media	21.4158	21.4158	2.0948	17.7041	1.6169	0.0000	0.0000	11.0083	10.4075	48.6%	40.3%
	Underdrain		17.7041	8.3127		9.3915	0.0000	0.0000				
Total		25.8535		11.7245			0.0000	0.0000	14.1288	11.7247		45.4%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.8292	1.8292	0.0460	1.6125	0.1708	0.0000	0.0000	1.2940	0.5352	29.3%	5.1%
	Underdrain		1.6125	0.4891		1.1232	0.0000	0.0000				
Bioretention S	Pond + Media	8.7415	8.7415	0.8742	7.1730	0.6943	0.0000	0.0000	4.5238	4.2176	48.2%	39.9%
	Underdrain		7.1730	3.3434		3.8296	0.0000	0.0000				
Total		10.5707		4.7527			0.0000	0.0000	5.8179	4.7528		45.0%

Table G-5 2008 Flows and Loads of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.6296	1.6296	0.0040	1.5917	0.0339	0.0000	0.0000	1.2753	0.3663	22.3%	3.8%
	Underdrain		1.5917	0.3623		1.2415	0.0121	0.0000				
Bioretention S	Pond + Media	7.9251	7.9251	0.0183	7.7534	0.1534	0.0000	0.0000	6.1830	1.7982	22.5%	18.7%
	Underdrain		7.7534	1.7798		6.0297	0.0561	0.0000				
Total		9.5547		2.1644			0.0682	0.0000	7.4584	2.1645		22.5%

total rainfall (in)	14.221
drainage area (ac)	27.228
overall runoff coeff	0.296

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1,047,310	1,047,310	81,356	949,744	16,208	0	0	455,492	591,818	56.5%	11.0%
	Underdrain		949,744	510,462		439,283	0	0				
Bioretention S	Pond + Media	4,352,860	4,352,860	326,368	3,964,315	62,170	0	0	1,882,776	2,470,085	56.7%	45.7%
	Underdrain		3,964,315	2,143,704		1,820,606	0	0				
Total		5,400,170		3,061,890			0	0	2,338,267	3,061,903		56.7%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.8582	4.8582	0.0612	4.7360	0.0610	0.0000	0.0000	2.8860	1.9734	40.6%	6.9%
	Underdrain		4.7360	1.9122		2.8251	0.0013	0.0000				
Bioretention S	Pond + Media	23.6268	23.6268	0.2857	23.0670	0.2740	0.0000	0.0000	13.9556	9.6791	41.0%	34.0%
	Underdrain		23.0670	9.3933		13.6816	0.0079	0.0000				
Total		28.4849		11.6524			0.0092	0.0000	16.8417	11.6524		40.9%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.8627	1.8627	0.1354	1.7018	0.0255	0.0000	0.0000	0.9277	0.9350	50.2%	8.5%
	Underdrain		1.7018	0.7996		0.9022	0.0000	0.0000				
Bioretention S	Pond + Media	9.1060	9.1060	1.0959	7.9036	0.1065	0.0000	0.0000	3.6043	5.5017	60.4%	50.2%
	Underdrain		7.9036	4.4057		3.4978	0.0000	0.0000				
Total		10.9687		6.4366			0.0000	0.0000	4.5320	6.4367		58.7%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.3295	3.3295	0.1722	3.1069	0.0505	0.0000	0.0000	1.7015	1.6280	48.9%	8.3%
	Underdrain		3.1069	1.4558		1.6510	0.0000	0.0000				
Bioretention S	Pond + Media	16.2402	16.2402	1.4320	14.5928	0.2155	0.0000	0.0000	6.8261	9.4142	58.0%	48.1%
	Underdrain		14.5929	7.9822		6.6106	0.0000	0.0000				
Total		19.5698		11.0422			0.0000	0.0000	8.5276	11.0422		56.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.5183	1.5183	0.0233	1.4754	0.0195	0.0000	0.0000	0.8887	0.6296	41.5%	7.1%
	Underdrain		1.4754	0.6064		0.8692	0.0000	0.0000				
Bioretention S	Pond + Media	7.3840	7.3840	0.4466	6.8554	0.0819	0.0000	0.0000	3.0625	4.3215	58.5%	48.5%
	Underdrain		6.8554	3.8749		2.9806	0.0000	0.0000				
Total		8.9023		4.9513			0.0000	0.0000	3.9512	4.9511		55.6%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.6011	0.6011	0.0091	0.5842	0.0077	0.0000	0.0000	0.3509	0.2502	41.6%	7.1%
	Underdrain		0.5842	0.2411		0.3432	0.0000	0.0000				
Bioretention S	Pond + Media	2.9230	2.9230	0.1746	2.7161	0.0323	0.0000	0.0000	1.2084	1.7146	58.7%	48.7%
	Underdrain		2.7161	1.5400		1.1762	0.0000	0.0000				
Total		3.5241		1.9648			0.0000	0.0000	1.5593	1.9647		55.8%

Table G-6 2009 Flows and Loads of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.8312	4.8312	0.0127	3.8121	1.0064	0.0000	0.0000	4.4037	0.3581	7.4%	1.3%
	Underdrain		3.8121	0.3454		3.3972	0.0000	0.0694				
Bioretention S	Pond + Media	23.4737	23.4737	0.0619	18.5647	4.8472	0.0000	0.0000	21.3683	1.7633	7.5%	6.2%
	Underdrain		18.5647	1.7015		16.5211	0.0000	0.3421				
Total		28.3049		2.1215			0.0000	0.4116	25.7720	2.1214		7.5%

total rainfall (in)	31.205
drainage area (ac)	27.228
overall runoff coeff	0.400

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2,017,502	2,017,502	263,504	1,648,068	105,934	0	0	1,016,198	997,693	49.5%	9.6%
	Underdrain		1,648,068	734,023		910,264	0	3,611				
Bioretention S	Pond + Media	8,362,570	8,362,570	1,066,588	6,878,127	417,870	0	0	4,203,736	4,143,785	49.6%	39.9%
	Underdrain		6,878,127	3,076,512		3,785,867	0	15,049				
Total		10,380,072		5,140,627			0	18,660	5,219,934	5,141,478		49.5%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	9.0796	9.0796	0.1995	8.5394	0.3407	0.0000	0.0000	5.9631	2.9377	32.4%	5.5%
	Underdrain		8.5394	2.7368		5.6224	0.0000	0.1787				
Bioretention S	Pond + Media	43.9797	43.9797	0.9367	41.5254	1.5177	0.0000	0.0000	28.7726	14.3345	32.6%	27.0%
	Underdrain		41.5254	13.3911		27.2548	0.0000	0.8726				
Total		53.0593		17.2641			0.0000	1.0513	34.7357	17.2723		32.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.3407	4.3407	0.5187	3.1211	0.7009	0.0000	0.0000	2.6129	1.7190	39.6%	6.7%
	Underdrain		3.1211	1.1999		1.9120	0.0000	0.0089				
Bioretention S	Pond + Media	21.1445	21.1445	4.1596	13.7534	3.2315	0.0000	0.0000	10.3861	10.7514	50.8%	42.2%
	Underdrain		13.7534	6.5913		7.1546	0.0000	0.0070				
Total		25.4852		12.4695			0.0000	0.0159	12.9990	12.4703		48.9%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	7.0600	7.0600	0.6042	5.6522	0.8036	0.0000	0.0000	4.3169	2.7114	38.4%	6.5%
	Underdrain		5.6522	2.1063		3.5133	0.0000	0.0318				
Bioretention S	Pond + Media	34.3972	34.3972	5.0243	25.6700	3.7028	0.0000	0.0000	17.6418	16.7181	48.6%	40.3%
	Underdrain		25.6700	11.6916		13.9390	0.0000	0.0373				
Total		41.4573		19.4264			0.0000	0.0691	21.9587	19.4295		46.9%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.8699	2.8699	0.0735	2.6911	0.1053	0.0000	0.0000	1.8567	0.9647	33.6%	5.7%
	Underdrain		2.6911	0.8907		1.7513	0.0000	0.0486				
Bioretention S	Pond + Media	13.9085	13.9085	1.3992	12.0775	0.4317	0.0000	0.0000	6.7812	7.0933	51.0%	42.3%
	Underdrain		12.0775	5.6926		6.3495	0.0000	0.0339				
Total		16.7784		8.0561			0.0000	0.0825	8.6379	8.0580		48.0%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.1487	1.1487	0.0295	1.0696	0.0497	0.0000	0.0000	0.7464	0.3828	33.3%	5.7%
	Underdrain		1.0696	0.3532		0.6967	0.0000	0.0195				
Bioretention S	Pond + Media	5.5411	5.5411	0.5572	4.7886	0.1954	0.0000	0.0000	2.7130	2.8145	50.8%	42.1%
	Underdrain		4.7886	2.2567		2.5176	0.0000	0.0136				
Total		6.6898		3.1966			0.0000	0.0331	3.4594	3.1973		47.8%

Table G-7 2010 Flows and Loads of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.4796	6.4796	0.0203	4.8296	1.6299	0.0000	0.0000	6.0265	0.5000	7.6%	1.3%
	Underdrain		4.8296	0.4798		4.3966	0.0694	0.0226				
Bioretention S	Pond + Media	31.4883	31.4883	0.0987	23.5906	7.7989	0.0000	0.0000	29.2597	2.4612	7.7%	6.4%
	Underdrain		23.5906	2.3624		21.4608	0.3421	0.1095				
Total		37.9680		2.9612			0.4116	0.1321	35.2862	2.9613		7.7%

total rainfall (in)	37.961
drainage area (ac)	27.228
overall runoff coeff	0.441

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2,312,001	2,312,001	387,205	1,592,080	332,727	0	0	1,263,556	1,050,409	45.4%	8.8%
	Underdrain		1,592,080	663,307		930,829	3,611	1,648				
Bioretention S	Pond + Media	9,584,794	9,584,794	1,600,019	6,648,047	1,336,741	0	0	5,217,168	4,375,824	45.6%	36.7%
	Underdrain		6,648,047	2,776,187		3,880,427	15,049	6,851				
Total		11,896,795		5,426,718			18,660	8,499	6,480,724	5,426,233		45.5%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	9.7762	9.7762	0.3118	8.2307	1.2337	0.0000	0.0000	7.0999	2.6894	27.0%	4.6%
	Underdrain		8.2307	2.3777		5.8662	0.1787	0.1656				
Bioretention S	Pond + Media	47.3577	47.3577	1.4998	40.0958	5.7624	0.0000	0.0000	34.2941	13.1310	27.2%	22.6%
	Underdrain		40.0958	11.6317		28.5318	0.8726	0.8052				
Total		57.1339		15.8209			1.0513	0.9708	41.3941	15.8204		27.2%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	5.1781	5.1781	0.7758	3.2117	1.1907	0.0000	0.0000	3.2410	1.9416	37.4%	6.4%
	Underdrain		3.2117	1.1659		2.0504	0.0089	0.0044				
Bioretention S	Pond + Media	25.2010	25.2010	6.1253	13.7674	5.3082	0.0000	0.0000	12.7752	12.4307	49.3%	40.9%
	Underdrain		13.7674	6.3056		7.4671	0.0070	0.0021				
Total		30.3791		14.3727			0.0159	0.0065	16.0163	14.3723		47.3%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	8.0449	8.0449	0.9093	5.6474	1.4882	0.0000	0.0000	5.1869	2.8688	35.5%	6.1%
	Underdrain		5.6474	1.9598		3.6987	0.0318	0.0209				
Bioretention S	Pond + Media	39.1883	39.1883	7.5008	24.9918	6.6957	0.0000	0.0000	20.9913	18.2186	46.4%	38.5%
	Underdrain		24.9918	10.7190		14.2956	0.0373	0.0157				
Total		47.2332		21.0889			0.0691	0.0366	26.1782	21.0874		44.6%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.0883	3.0883	0.1111	2.6000	0.3772	0.0000	0.0000	2.1955	0.8975	28.6%	4.9%
	Underdrain		2.6000	0.7865		1.8183	0.0486	0.0438				
Bioretention S	Pond + Media	14.9614	14.9614	2.0753	11.2761	1.6100	0.0000	0.0000	7.8103	7.1681	47.8%	39.5%
	Underdrain		11.2761	5.0936		6.2003	0.0339	0.0169				
Total		18.0496		8.0664			0.0825	0.0608	10.0058	8.0656		44.5%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.2382	1.2382	0.0449	1.0353	0.1580	0.0000	0.0000	0.8830	0.3571	28.4%	4.9%
	Underdrain		1.0353	0.3122		0.7250	0.0195	0.0176				
Bioretention S	Pond + Media	5.9679	5.9679	0.8334	4.4694	0.6651	0.0000	0.0000	3.1262	2.8484	47.6%	39.3%
	Underdrain		4.4694	2.0154		2.4611	0.0136	0.0068				
Total		7.2060		3.2059			0.0331	0.0244	4.0092	3.2056		44.3%

Table G-8 2007-2010 Flows and Loads of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	20.6852	20.6852	0.0627	16.4383	4.1846	0.0000	0.0000	18.8993	1.7634	8.5%	1.5%
	Underdrain		16.4383	1.7007		14.7147	0.0000	0.0226				
Bioretention S	Pond + Media	100.4797	100.4797	0.3048	80.1614	20.0132	0.0000	0.0000	91.6934	8.6768	8.6%	7.2%
	Underdrain		80.1614	8.3718		71.6802	0.0000	0.1095				
Total		121.1649		10.4400			0.0000	0.1321	110.5927	10.4401		8.6%

total rainfall (in)	131.314
drainage area (ac)	27.228
overall runoff coeff	0.407

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	8,403,566	8,403,566	1,090,944	6,525,893	786,737	0	0	4,353,352	4,048,566	48.2%	9.4%
	Underdrain		6,525,894	2,957,554		3,566,615	0	1,648				
Bioretention S	Pond + Media	34,805,558	34,805,558	4,466,165	27,206,395	3,133,038	0	0	17,948,646	16,850,060	48.4%	39.0%
	Underdrain		27,206,395	12,383,613		14,815,608	0	6,851				
Total		43,209,124		20,898,275			0	8,499	22,301,998	20,898,626		48.4%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	37.5666	37.5666	0.8689	33.8248	2.8730	0.0000	0.0000	25.8870	11.5140	30.6%	5.2%
	Underdrain		33.8248	10.6438		23.0140	0.0000	0.1656				
Bioretention S	Pond + Media	181.7779	181.7779	4.1311	164.4413	13.2058	0.0000	0.0000	124.7356	56.2372	30.9%	25.6%
	Underdrain		164.4413	52.0996		111.5298	0.0000	0.8052				
Total		219.3446		67.7434			0.0000	0.9708	150.6226	67.7512		30.9%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	18.2594	18.2594	2.1939	13.0471	3.0184	0.0000	0.0000	10.9416	7.3133	40.1%	6.8%
	Underdrain		13.0471	5.1193		7.9232	0.0000	0.0044				
Bioretention S	Pond + Media	88.8761	88.8761	17.5653	57.7831	13.5277	0.0000	0.0000	43.1772	45.6969	51.4%	42.7%
	Underdrain		57.7831	28.1314		29.6495	0.0000	0.0021				
Total		107.1355		53.0098			0.0000	0.0065	54.1188	53.0102		49.5%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	29.2917	29.2917	2.5763	22.8408	3.8746	0.0000	0.0000	18.0402	11.2306	38.3%	6.5%
	Underdrain		22.8408	8.6537		14.1656	0.0000	0.0209				
Bioretention S	Pond + Media	142.6522	142.6522	21.4884	103.6695	17.4940	0.0000	0.0000	73.2714	69.3652	48.6%	40.3%
	Underdrain		103.6695	47.8756		55.7774	0.0000	0.0157				
Total		171.9439		80.5941			0.0000	0.0366	91.3115	80.5957		46.9%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	11.9142	11.9142	0.3160	10.7114	0.8867	0.0000	0.0000	8.0613	3.8091	32.0%	5.5%
	Underdrain		10.7114	3.4926		7.1746	0.0000	0.0438				
Bioretention S	Pond + Media	57.6696	57.6696	6.0159	47.9132	3.7405	0.0000	0.0000	28.6623	28.9904	50.3%	41.7%
	Underdrain		47.9132	22.9738		24.9218	0.0000	0.0169				
Total		69.5838		32.7983			0.0000	0.0608	36.7236	32.7994		47.1%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.8172	4.8172	0.1295	4.3016	0.3861	0.0000	0.0000	3.2743	1.5253	31.7%	5.4%
	Underdrain		4.3016	1.3957		2.8881	0.0000	0.0176				
Bioretention S	Pond + Media	23.1735	23.1735	2.4394	19.1471	1.5870	0.0000	0.0000	11.5715	11.5952	50.0%	41.4%
	Underdrain		19.1471	9.1555		9.9845	0.0000	0.0068				
Total		27.9907		13.1200			0.0000	0.0244	14.8458	13.1205		46.9%

Table G-9 Summary of Flow and Load Removed of Subbasin 260 BMP Performance Evaluation Modeling

FLOW

BMP	Flow removed (ac-ft)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	0.5389	0.3663	0.3581	0.5000	1.7634	7.0%	22.3%	7.4%	7.6%	8.5%	1.2%	3.8%	1.3%	1.3%	1.5%
Bioretention S	2.6541	1.7982	1.7633	2.4612	8.6768	7.1%	22.5%	7.5%	7.7%	8.6%	5.9%	18.7%	6.2%	6.4%	7.2%
Total	3.1930	2.1645	2.1214	2.9613	10.4401						7.0%	22.5%	7.5%	7.7%	8.6%

BACT

BMP	Load removed (10^6)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	1,408,647	591,818	997,693	1,050,409	4,048,566	46.5%	56.5%	49.5%	45.4%	48.2%	9.1%	11.0%	9.6%	8.8%	9.4%
Bioretention S	5,860,367	2,470,085	4,143,785	4,375,824	16,850,060	46.9%	56.7%	49.6%	45.6%	48.4%	37.7%	45.7%	39.9%	36.7%	39.0%
Total	7,269,013	3,061,903	5,141,478	5,426,233	20,898,626						46.8%	56.7%	49.5%	45.5%	48.4%

ORGN

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	3.9135	1.9734	2.9377	2.6894	11.5140	28.3%	40.6%	32.4%	27.0%	30.6%	4.9%	6.9%	5.5%	4.6%	5.2%
Bioretention S	19.0926	9.6791	14.3345	13.1310	56.2372	28.6%	41.0%	32.6%	27.2%	30.9%	23.7%	34.0%	27.0%	22.6%	25.6%
Total	23.0061	11.6524	17.2723	15.8204	67.7512						28.5%	40.9%	32.6%	27.2%	30.9%

NH3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	2.7178	0.9350	1.7190	1.9416	7.3133	39.5%	50.2%	39.6%	37.4%	40.1%	6.7%	8.5%	6.7%	6.4%	6.8%
Bioretention S	17.0132	5.5017	10.7514	12.4307	45.6969	50.9%	60.4%	50.8%	49.3%	51.4%	42.2%	50.2%	42.2%	40.9%	42.7%
Total	19.7310	6.4367	12.4703	14.3723	53.0102						49.0%	58.7%	48.9%	47.3%	49.5%

NO3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	4.0224	1.6280	2.7114	2.8688	11.2306	37.0%	48.9%	38.4%	35.5%	38.3%	6.3%	8.3%	6.5%	6.1%	6.5%
Bioretention S	25.0142	9.4142	16.7181	18.2186	69.3652	47.4%	58.0%	48.6%	46.4%	48.6%	39.3%	48.1%	40.3%	38.5%	40.3%
Total	29.0367	11.0422	19.4295	21.0874	80.5957						45.6%	56.4%	46.9%	44.6%	46.9%

ORGP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	1.3173	0.6296	0.9647	0.8975	3.8091	29.7%	41.5%	33.6%	28.6%	32.0%	5.1%	7.1%	5.7%	4.9%	5.5%
Bioretention S	10.4075	4.3215	7.0933	7.1681	28.9904	48.6%	58.5%	51.0%	47.8%	50.3%	40.3%	48.5%	42.3%	39.5%	41.7%
Total	11.7247	4.9511	8.0580	8.0656	32.7994						45.4%	55.6%	48.0%	44.5%	47.1%

ORTHOP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	0.5352	0.2502	0.3828	0.3571	1.5253	29.3%	41.6%	33.3%	28.4%	31.7%	5.1%	7.1%	5.7%	4.9%	5.4%
Bioretention S	4.2176	1.7146	2.8145	2.8484	11.5952	48.2%	58.7%	50.8%	47.6%	50.0%	39.9%	48.7%	42.1%	39.3%	41.4%
Total	4.7528	1.9647	3.1973	3.2056	13.1205						45.0%	55.8%	47.8%	44.3%	46.9%

H. Subbasin 270 BMP Performance Evaluation Modeling

Site Description and Land uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 270 is Rosedale Park bounded by Ruiz St to the north and Dartmouth St to the south as shown in Exhibit H-1. Apache Creek runs through the park. Existing facilities in the park include soccer fields and baseball fields. A YMCA facility is adjacent to the park as shown in Exhibit H-1.

As shown in Exhibit H-1, a significant area of the park is in the effective 100-year floodplain and excluded from locating BMP. The open area west of Apache Creek appears to be a filled area. It was decided not to disturb this area. A site for a BMP was considered to the east of the YMCA facility but was decided to be not suitable because the drainage area would cross into another subbasin. Following evaluation of site conditions including floodplain boundary and discussion with the River Authority, a bioretention was proposed at the north end of the park as shown in Exhibits H-1 and H-2. Based on the size classification in the BMP Tool Database, the size was considered "average."

The drainage area to the BMP site was delineated using ArcHydro and the DEM provided by the River Authority and determined to be 1.689 acres. The drainage area is mostly a fire station. The land use is classified as commercial. The land uses and their corresponding impervious cover percentages from the 2017 land use data provided by the River Authority are used to determine the pervious and impervious areas within the delineated area, as listed in Table H-1.

Table H-1 Land uses of Subbasin 270 BMP Site

Land use	IC%	Pervious Area (ac)	Impervious Area (ac)	Total Area (ac)
Commercial	90	0.138	1.240	1.378
Transportation	90	0.031	0.280	0.311
TOTAL	90	0.169	1.520	1.689

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQV for the selected BMP site is:
1.5"/12 x 0.6 x 1.520 ac x 1.2 = 0.137 ac-ft

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority's LID Manual (SARA, 2019; page B-117). The WQV and surface area of the bioretention are shown in Table H-2.

Table H-2 Water Quality Volume and Surface Area of Subbasin 270 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioretention	0.1731	0.0829
Required	0.1370	

Note: Surface area is the area at the water level of the WQV.

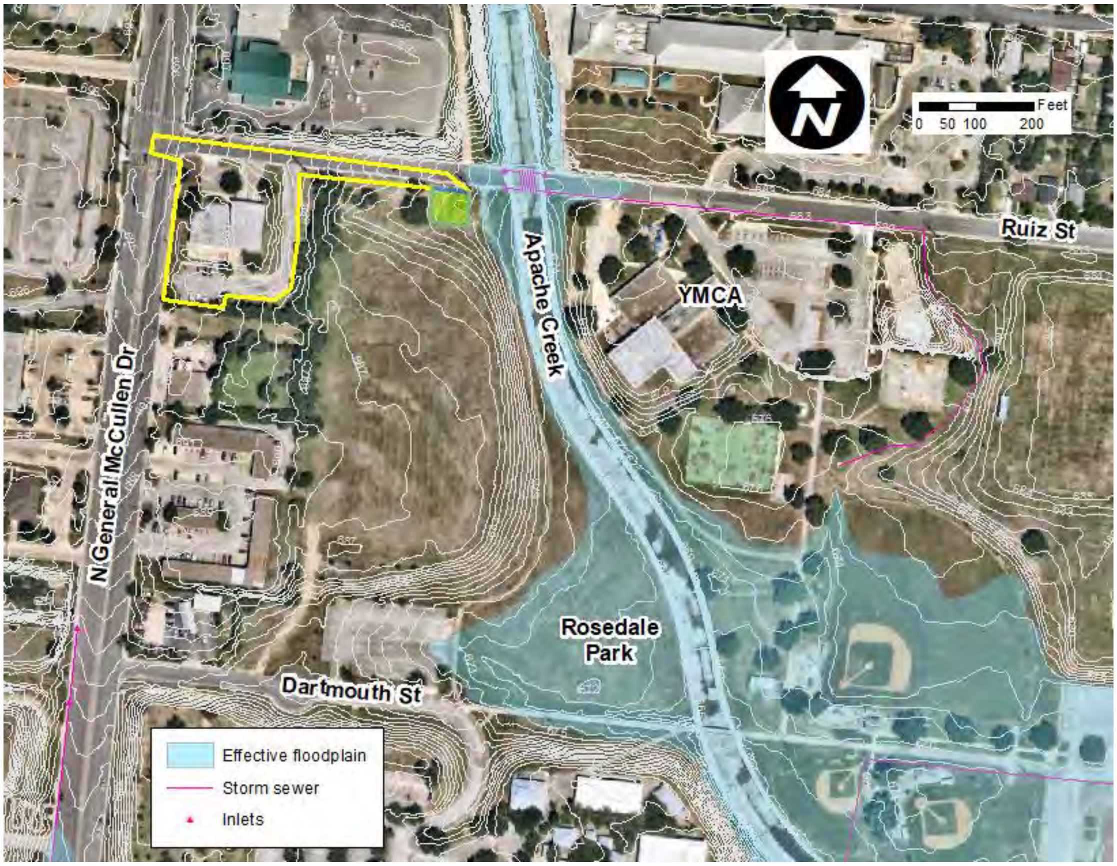


Exhibit H-1 Delineated Drainage Area to Subbasin 270 BMP Site

Exhibit H-2 Proposed BMP Layout on Subbasin 270 Site

Modeling Bioretention in HSPF

Refer to the discussion in Section F.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table H-3 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Table H-3 EC Concentrations of Subbasin 270 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioretention	43,044	8,455	7,413	8,540

Tables H-4 to H-7 list the model output annual inflows and outflows of the bioretention in Subbasin 150 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed and the corresponding removal percentages (or BMP performance) are also listed. Table H-8 shows the same set of information but for the 4-year total. The loads removed and removal percentages calculated are summarized in Table H-9 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

Table H-4 2007 Flows and Loads of Subbasin 270 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	4.0551	4.0551	0.0139	3.4035	0.6378	0.0000	0.0000	3.7287	0.3235	8.0%
	Underdrain		3.4035	0.3096		3.0909	0.0000	0.0029			

total rainfall (in)	47.927
drainage area (ac)	1.688
overall runoff coeff	0.601

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	1,036,699	1,036,699	116,524	842,458	77,716	0	0	525,421	511,272	49.3%
	Underdrain		842,458	394,747		447,705	0	7			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	7.1461	7.1461	0.1396	6.5855	0.4209	0.0000	0.0000	4.9441	2.1964	30.7%
	Underdrain		6.5855	2.0568		4.5232	0.0000	0.0055			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	3.6217	3.6217	0.3807	2.7882	0.4529	0.0000	0.0000	2.1026	1.5191	41.9%
	Underdrain		2.7882	1.1384		1.6497	0.0000	0.0000			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	5.7304	5.7304	0.4486	4.6684	0.6135	0.0000	0.0000	3.4658	2.2646	39.5%
	Underdrain		4.6684	1.8160		2.8523	0.0000	0.0001			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.2923	2.2923	0.0508	2.1093	0.1321	0.0000	0.0000	1.5533	0.7378	32.2%
	Underdrain		2.1093	0.6870		1.4211	0.0000	0.0012			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.9232	0.9232	0.0206	0.8491	0.0535	0.0000	0.0000	0.6262	0.2965	32.1%
	Underdrain		0.8491	0.2759		0.5728	0.0000	0.0005			

Table H-5 2008 Flows and Loads of Subbasin 270 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	0.8571	0.8571	0.0020	0.8550	0.0000	0.0000	0.0000	0.6456	0.2144	24.9%
	Underdrain		0.8550	0.2124		0.6456	0.0029	0.0000			

total rainfall (in)	14.221
drainage area (ac)	1.688
overall runoff coeff	0.428

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	365,205	365,205	24,939	340,266	0	0	0	146,130	219,081	60.0%
	Underdrain		340,266	194,143		146,130	7	0			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.5552	2.5552	0.0283	2.5269	0.0000	0.0000	0.0000	1.4225	1.1383	44.5%
	Underdrain		2.5269	1.1100		1.4225	0.0055	0.0000			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.9971	0.9971	0.0623	0.9348	0.0000	0.0000	0.0000	0.4638	0.5333	53.5%
	Underdrain		0.9348	0.4711		0.4638	0.0000	0.0000			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	1.7689	1.7689	0.0808	1.6880	0.0000	0.0000	0.0000	0.8388	0.9302	52.6%
	Underdrain		1.6880	0.8494		0.8388	0.0001	0.0000			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.7986	0.7986	0.0108	0.7877	0.0000	0.0000	0.0000	0.4376	0.3621	45.3%
	Underdrain		0.7877	0.3513		0.4376	0.0012	0.0000			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.3161	0.3161	0.0042	0.3119	0.0000	0.0000	0.0000	0.1727	0.1439	45.5%
	Underdrain		0.3119	0.1397		0.1727	0.0005	0.0000			

Table H-6 2009 Flows and Loads of Subbasin 270 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	2.5355	2.5355	0.0074	2.0552	0.4729	0.0000	0.0000	2.2796	0.2140	8.4%
	Underdrain		2.0552	0.2066		1.8067	0.0000	0.0419			

total rainfall (in)	31.205
drainage area (ac)	1.688
overall runoff coeff	0.578

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	697,796	697,796	74,736	598,647	24,412	0	0	344,827	351,676	50.4%
	Underdrain		598,647	276,879		320,415	0	1,292			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	4.7308	4.7308	0.0815	4.5493	0.0999	0.0000	0.0000	3.0094	1.6237	34.3%
	Underdrain		4.5493	1.5414		2.9095	0.0000	0.0977			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.2992	2.2992	0.2308	1.7394	0.3290	0.0000	0.0000	1.3620	0.9324	40.6%
	Underdrain		1.7394	0.7014		1.0330	0.0000	0.0049			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	3.7389	3.7389	0.2662	3.1121	0.3606	0.0000	0.0000	2.2401	1.4813	39.6%
	Underdrain		3.1121	1.2146		1.8795	0.0000	0.0175			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	1.4971	1.4971	0.0300	1.4348	0.0323	0.0000	0.0000	0.9385	0.5320	35.5%
	Underdrain		1.4348	0.5018		0.9062	0.0000	0.0265			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.5927	0.5927	0.0119	0.5675	0.0133	0.0000	0.0000	0.3717	0.2104	35.5%
	Underdrain		0.5675	0.1984		0.3583	0.0000	0.0107			

Table H-7 2010 Flows and Loads of Subbasin 270 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	3.4019	3.4019	0.0113	2.7073	0.6832	0.0000	0.0000	3.1325	0.2997	8.7%
	Underdrain		2.7073	0.2883		2.4493	0.0419	0.0116			

total rainfall (in)	37.961
drainage area (ac)	1.688
overall runoff coeff	0.637

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	799,974	799,974	131,720	588,546	79,709	0	0	418,912	374,919	46.8%
	Underdrain		588,546	243,263		339,204	1,292	7,435			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	5.0943	5.0943	0.1560	4.5040	0.4343	0.0000	0.0000	3.6012	1.4531	28.0%
	Underdrain		4.5040	1.2979		3.1669	0.0977	0.1378			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.7339	2.7339	0.4136	1.8299	0.4905	0.0000	0.0000	1.6455	1.0735	39.2%
	Underdrain		1.8299	0.6601		1.1551	0.0049	0.0198			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	4.2578	4.2578	0.4737	3.1863	0.5977	0.0000	0.0000	2.6580	1.5639	36.6%
	Underdrain		3.1863	1.0907		2.0603	0.0175	0.0534			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	1.6096	1.6096	0.0554	1.4205	0.1337	0.0000	0.0000	1.1125	0.4844	29.6%
	Underdrain		1.4205	0.4292		0.9788	0.0265	0.0393			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	0.6376	0.6376	0.0221	0.5617	0.0538	0.0000	0.0000	0.4412	0.1913	29.5%
	Underdrain		0.5617	0.1693		0.3874	0.0107	0.0158			

Table H-8 2007-2010 Flows and Loads of Subbasin 270 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal
Bioretention	Pond + Media	10.8496	10.8496	0.0346	9.0211	1.7939	0.0000	0.0000	9.7864	1.0516	9.7%
	Underdrain		9.0211	1.0169		7.9926	0.0000	0.0116			

total rainfall (in)	131.314
drainage area (ac)	1.688
overall runoff coeff	0.587

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal
Bioretention	Pond + Media	2,899,674	2,899,674	347,919	2,369,918	181,837	0	0	1,435,291	1,456,948	50.2%
	Underdrain		2,369,918	1,109,032		1,253,454	0	7,435			

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	19.5264	19.5264	0.4055	18.1658	0.9551	0.0000	0.0000	12.9772	6.4114	32.8%
	Underdrain		18.1658	6.0060		12.0221	0.0000	0.1378			

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	9.6519	9.6519	1.0873	7.2923	1.2723	0.0000	0.0000	5.5738	4.0583	42.0%
	Underdrain		7.2923	2.9710		4.3015	0.0000	0.0198			

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	15.4960	15.4960	1.2693	12.6549	1.5718	0.0000	0.0000	9.2026	6.2400	40.3%
	Underdrain		12.6549	4.9707		7.6308	0.0000	0.0534			

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	6.1975	6.1975	0.1470	5.7524	0.2981	0.0000	0.0000	4.0419	2.1164	34.1%
	Underdrain		5.7524	1.9694		3.7437	0.0000	0.0393			

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal
Bioretention	Pond + Media	2.4696	2.4696	0.0588	2.2902	0.1206	0.0000	0.0000	1.6117	0.8421	34.1%
	Underdrain		2.2902	0.7833		1.4911	0.0000	0.0158			

Table H-9 Summary of Flow and Load Removed of Subbasin 270 BMP Performance Evaluation Modeling

Constituent	Flow/Load removed (ac-ft)					% removed				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Flow	0.3235	0.2144	0.2140	0.2997	1.0516	8.0%	24.9%	8.4%	8.7%	9.7%
BACT	511,272	219,081	351,676	374,919	1,456,948	49.3%	60.0%	50.4%	46.8%	50.2%
ORGN	2.1964	1.1383	1.6237	1.4531	6.4114	30.7%	44.5%	34.3%	28.0%	32.8%
NH3N	1.5191	0.5333	0.9324	1.0735	4.0583	41.9%	53.5%	40.6%	39.2%	42.0%
NO3N	2.2646	0.9302	1.4813	1.5639	6.2400	39.5%	52.6%	39.6%	36.6%	40.3%
ORGP	0.7378	0.3621	0.5320	0.4844	2.1164	32.2%	45.3%	35.5%	29.6%	34.1%
ORTHOP	0.2965	0.1439	0.2104	0.1913	0.8421	32.1%	45.5%	35.5%	29.5%	34.1%

I. Subbasin 310 BMP Performance Evaluation Modeling

Site Description and Land uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 310 is Lee's Creek Park to the east of Hillcrest Dr as shown in Exhibit I-1. The creek is not a FEMA studied stream and there is no effective floodplain delineated.

Exhibits I-1 and I-2 show delineated drainage area and proposed BMP layout, respectively, for USAR Subbasin 310.

Following evaluation of site conditions and discussion the River Authority, a bioswale was proposed north of the creek and a bioretention south of the creek as shown in Exhibits I-1 and I-2. Based on the size classification in the BMP Tool Database, the bioretention was considered "average."

The drainage areas to the bioswale and bioretention were delineated using Arc Hydro and the DEM data provided by the River Authority. The areas were determined to be 0.175 acre for the bioswale and 5.022 acres for the bioretention. As shown in Exhibit I-1, the land use in the delineated drainage areas include single-family residential and transportation.

The land uses and their corresponding impervious cover percentages from the 2017 land use data provided by the River Authority are used to determine the pervious (Per.) and impervious (Imp.) areas within the delineated drainage areas, as listed in Table I-1.

Table I-1 Land uses of Subbasin 310 BMP Sites

Land use	IC%	Bioswale			IC%	Bioretention		
		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)
Residential Low Density	25	0.014	0.005	0.019	25	3.332	1.110	4.442
Transportation	90	0.016	0.140	0.156	90	0.058	0.522	0.580
TOTAL	82.9	0.030	0.145	0.175	32.5	3.390	1.632	5.022

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQVs for the selected BMP sites are:
1.5"/12 x 0.6 x 0.145 ac x 1.2 = 0.013 ac-ft for Bioswale
1.5"/12 x 0.6 x 1.632 ac x 1.2 = 0.147 ac-ft for Bioretention

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority's LID Manual (SARA, 2019; page B-117). The water quality volume and surface area of each BMP are shown in Table I-2.

Table I-2 Water Quality Volume and Surface Area of Subbasin 310 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioswale	0.0189	0.0131
Bioretention	0.1758	0.0864
Total	0.1947	
Required	0.1600	

Note: Surface area is the area at the water level of the WQV.

Exhibit I-1 Delineated Drainage Area to Subbasin 310 BMP Site

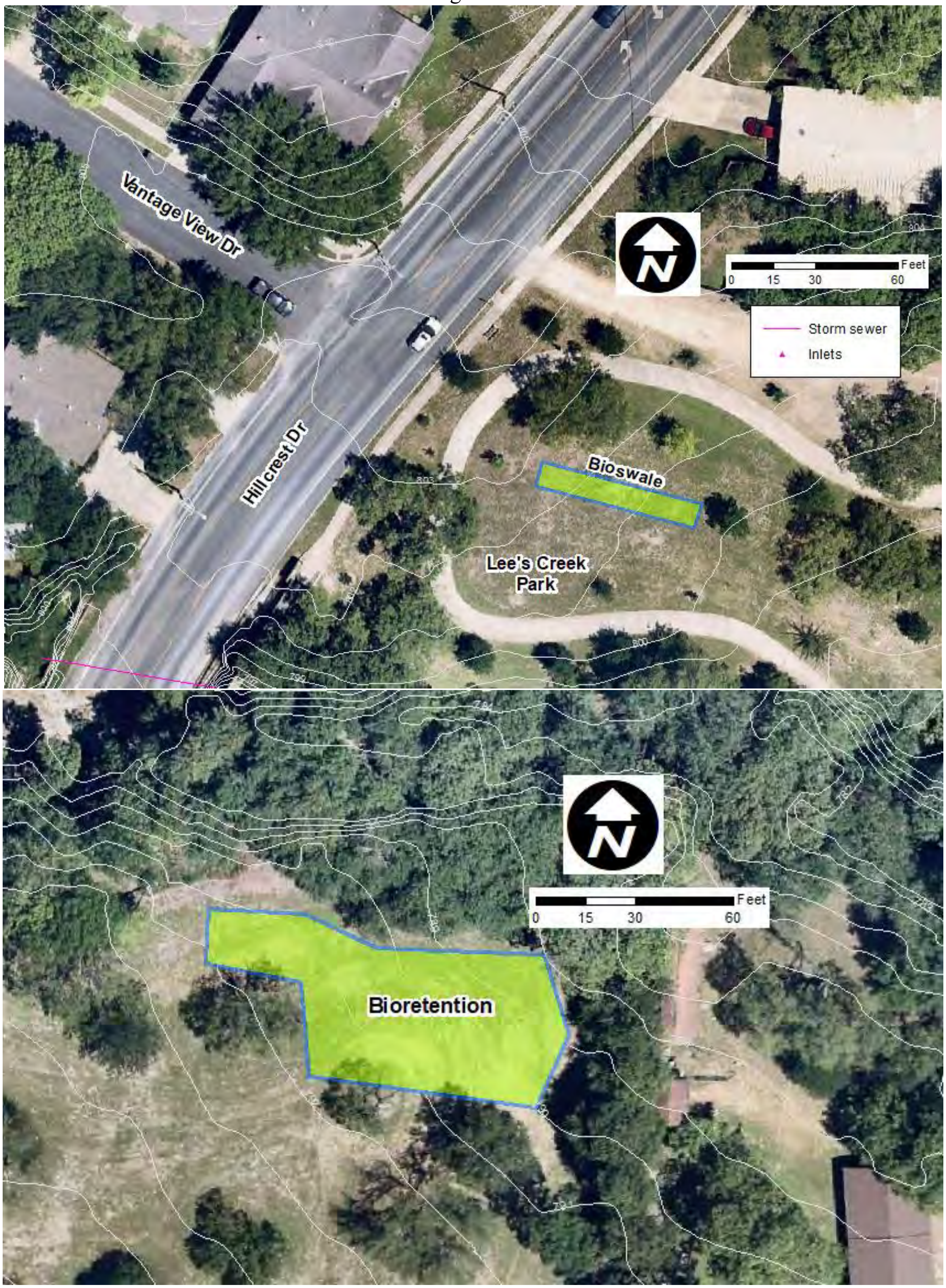


Exhibit I-2 Proposed BMP Layout on Subbasin 310 Site

Modeling Bioswales in HSPF

Refer to the discussion in Section E.

Page B-158 of the River Authority's LID Manual requires that a bioswale be designed to safely convey the 25-year storm event, and Page B-40 requires that flow velocity generally not exceed 1 ft/sec in mulched swales or 3 ft/sec in grassed swales. Calculations listed in Table I-3 show that the proposed bioswale meet these requirements.

Table I-3 Hydraulic Parameters of Bioswale in USAR Subbasin 310

Hydraulic Parameters	Bioswale
Length (ft)	60
Drainage area (ac)	0.175
Bottom width (ft)	5
Side slope (xH:1V)	3
Depth of swale (ft)	0.75
Manning n	0.2
Longitudinal slope	0.02
25-yr rainfall intensity (in/hr)	11
Runoff coefficient	0.90
25-yr flow (cfs)	1.73
Flow depth (ft)	0.48 < 0.75 OK
Cross section area (ft^2)	3.09
Wetted perimeter (ft)	8.04
Hydraulic radius (ft)	0.38
Velocity (ft/s)	0.56 < 1 OK

Modeling Bioretention in HSPF

Refer to the discussion in Section F.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table I-4 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Tables I-5 to I-8 list the model output annual inflows and outflows of the bioretention in Subbasin 150 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed and the corresponding removal percentages (or BMP performance) are also listed. Table I-9 shows the same set of information but for the 4-year total.

Table I-4 EC Concentrations of Subbasin 310 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioswale	44,513	9,309	7,762	8,776
Bioretention	72,052	16,999	13,522	15,733
Overall	69,814	16,404	12,447	15,158

The constituent removal percentages were calculated in two approaches – based on individual input to a BMP and based on the total input coming from the total drainage area. The loads removed and removal percentages calculated are summarized in Table I-10 for easier comparison.

For the approach based on individual input to a BMP, the percent removal represents only the performance of the BMP in removing only the flow and loads that can enter the BMP. While this is the standard approach when evaluating BMP performance, it can be misleading when comparing BMPs because the total input to BMPs are not the same. For example, Table I-10 shows that the bioswale has a percentage removal of EC (4-year total about 51%) similar to the bioretention (4-year total about 49%) if comparing these two BMP types using the percent removal based on individual BMP inflow.

On the other hand, as listed in Table I-10 under the “Load Removed” columns, the bioswale could remove about 1.5×10^{11} EC load over the 2007 to 2010 period while the bioretention could remove from 2.6×10^{12} of EC load. Thus, when comparing BMP types it would be beneficial to also evaluate the percent load removal based on the total input from the drainage area. Because the bioswale is sized to treat a small area, the removal percentage based on total inputs is much smaller (about 3%) than that of the bioretention. The overall results are dominated by the performance of the bioretention (about 47%).

Thus, a complete BMP performance evaluation should not only compare percent load removal data, but also the size, cost, footprint area, etc. associated with the BMPs. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

Table I-5 2007 Flows and Loads of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.3885	0.3885	0.0016	0.3367	0.0502	0.0000	0.0000	0.3562	0.0320	8.2%	0.7%
	Underdrain		0.3367	0.0304		0.3061	0.0000	0.0002				
Bioretention	Pond + Media	4.4071	4.4071	0.0152	3.6120	0.7799	0.0000	0.0000	4.0743	0.3280	7.4%	6.8%
	Underdrain		3.6120	0.3127		3.2944	0.0000	0.0049				
Total		4.7956		0.3599			0.0000	0.0051	4.4305	0.3600		7.5%

total rainfall (in)	47.927
drainage area (ac)	5.198
overall runoff coeff	0.231

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	103,001	103,001	12,718	85,023	5,260	0	0	50,535	52,461	50.9%	2.6%
	Underdrain		85,023	39,743		45,275	0	5				
Bioretention	Pond + Media	1,949,510	1,949,510	230,052	1,527,330	192,131	0	0	1,022,535	926,974	47.5%	45.2%
	Underdrain		1,527,330	696,924		830,404	0	0				
Total		2,052,511		979,437			0	5	1,073,070	979,436		47.7%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.6822	0.6822	0.0147	0.6399	0.0276	0.0000	0.0000	0.4677	0.2136	31.3%	2.8%
	Underdrain		0.6399	0.1989		0.4401	0.0000	0.0009				
Bioretention	Pond + Media	7.0176	7.0176	0.1506	6.2631	0.6039	0.0000	0.0000	4.9882	2.0267	28.9%	26.3%
	Underdrain		6.2631	1.8761		4.3843	0.0000	0.0027				
Total		7.6999		2.2403			0.0000	0.0037	5.4559	2.2403		29.1%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.3231	0.3231	0.0388	0.2508	0.0334	0.0000	0.0000	0.1841	0.1390	43.0%	3.3%
	Underdrain		0.2508	0.1001		0.1507	0.0000	0.0000				
Bioretention	Pond + Media	3.9200	3.9200	0.4305	2.9172	0.5723	0.0000	0.0000	2.3303	1.5897	40.6%	37.5%
	Underdrain		2.9172	1.1591		1.7580	0.0000	0.0000				
Total		4.2430		1.7286			0.0000	0.0000	2.5144	1.7287		40.7%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.5164	0.5164	0.0449	0.4281	0.0434	0.0000	0.0000	0.3068	0.2096	40.6%	3.1%
	Underdrain		0.4281	0.1647		0.2634	0.0000	0.0000				
Bioretention	Pond + Media	6.1577	6.1577	0.4982	4.8878	0.7718	0.0000	0.0000	3.8048	2.3529	38.2%	35.3%
	Underdrain		4.8878	1.8547		3.0330	0.0000	0.0000				
Total		6.6741		2.5625			0.0000	0.0000	4.1116	2.5625		38.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2202	0.2202	0.0054	0.2061	0.0088	0.0000	0.0000	0.1478	0.0722	32.8%	2.6%
	Underdrain		0.2061	0.0668		0.1390	0.0000	0.0002				
Bioretention	Pond + Media	2.5766	2.5766	0.0623	2.3058	0.2085	0.0000	0.0000	1.7914	0.7847	30.5%	28.1%
	Underdrain		2.3058	0.7224		1.5829	0.0000	0.0006				
Total		2.7969		0.8569			0.0000	0.0008	1.9392	0.8569		30.6%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0892	0.0892	0.0022	0.0832	0.0037	0.0000	0.0000	0.0600	0.0291	32.7%	2.5%
	Underdrain		0.0832	0.0269		0.0562	0.0000	0.0001				
Bioretention	Pond + Media	1.0977	1.0977	0.0282	0.9638	0.1057	0.0000	0.0000	0.7727	0.3247	29.6%	27.4%
	Underdrain		0.9638	0.2966		0.6670	0.0000	0.0002				
Total		1.1868		0.3538			0.0000	0.0003	0.8327	0.3538		29.8%

Table I-6 2008 Flows and Loads of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0820	0.0820	0.0002	0.0818	0.0000	0.0000	0.0000	0.0613	0.0210	25.5%	2.1%
	Underdrain		0.0818	0.0207		0.0613	0.0002	0.0000				
Bioretention	Pond + Media	0.9209	0.9209	0.0023	0.9137	0.0050	0.0000	0.0000	0.7063	0.2195	23.7%	21.8%
	Underdrain		0.9137	0.2172		0.7013	0.0049	0.0000				
Total		1.0030		0.2405			0.0051	0.0000	0.7675	0.2405		23.9%

total rainfall (in)	14.221
drainage area (ac)	5.198
overall runoff coeff	0.163

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	36,100	36,100	2,311	33,789	0	0	0	14,305	21,800	60.4%	3.1%
	Underdrain		33,789	19,489		14,305	5	0				
Bioretention	Pond + Media	659,334	659,334	48,534	608,306	2,493	0	0	273,298	386,035	58.5%	55.5%
	Underdrain		608,306	337,500		270,806	0	0				
Total		695,434		407,834			5	0	287,604	407,835		58.6%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2429	0.2429	0.0025	0.2404	0.0000	0.0000	0.0000	0.1344	0.1095	44.9%	4.2%
	Underdrain		0.2404	0.1069		0.1344	0.0009	0.0000				
Bioretention	Pond + Media	2.3744	2.3744	0.0281	2.3390	0.0073	0.0000	0.0000	1.3575	1.0196	42.9%	38.9%
	Underdrain		2.3390	0.9916		1.3502	0.0027	0.0000				
Total		2.6173		1.1291			0.0037	0.0000	1.4918	1.1291		43.1%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0824	0.0824	0.0054	0.0770	0.0000	0.0000	0.0000	0.0381	0.0443	53.8%	3.9%
	Underdrain		0.0770	0.0389		0.0381	0.0000	0.0000				
Bioretention	Pond + Media	1.0460	1.0460	0.0719	0.9706	0.0035	0.0000	0.0000	0.5011	0.5449	52.1%	48.3%
	Underdrain		0.9706	0.4730		0.4976	0.0000	0.0000				
Total		1.1284		0.5892			0.0000	0.0000	0.5392	0.5892		52.2%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.1561	0.1561	0.0069	0.1492	0.0000	0.0000	0.0000	0.0740	0.0821	52.6%	4.0%
	Underdrain		0.1492	0.0753		0.0740	0.0000	0.0000				
Bioretention	Pond + Media	1.8748	1.8748	0.0925	1.7754	0.0069	0.0000	0.0000	0.9192	0.9556	51.0%	47.1%
	Underdrain		1.7754	0.8632		0.9123	0.0000	0.0000				
Total		2.0309		1.0378			0.0000	0.0000	0.9932	1.0377		51.1%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0764	0.0764	0.0010	0.0754	0.0000	0.0000	0.0000	0.0416	0.0350	45.7%	3.7%
	Underdrain		0.0754	0.0341		0.0416	0.0002	0.0000				
Bioretention	Pond + Media	0.8581	0.8581	0.0125	0.8428	0.0027	0.0000	0.0000	0.4840	0.3747	43.6%	40.1%
	Underdrain		0.8428	0.3622		0.4812	0.0006	0.0000				
Total		0.9345		0.4098			0.0008	0.0000	0.5255	0.4098		43.8%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0302	0.0302	0.0004	0.0299	0.0000	0.0000	0.0000	0.0164	0.0139	45.9%	3.8%
	Underdrain		0.0299	0.0135		0.0164	0.0001	0.0000				
Bioretention	Pond + Media	0.3397	0.3397	0.0049	0.3337	0.0011	0.0000	0.0000	0.1910	0.1489	43.8%	40.2%
	Underdrain		0.3337	0.1440		0.1900	0.0002	0.0000				
Total		0.3700		0.1628			0.0003	0.0000	0.2075	0.1628		44.0%

Table I-7 2009 Flows and Loads of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2428	0.2428	0.0008	0.1990	0.0430	0.0000	0.0000	0.2177	0.0210	8.7%	0.7%
	Underdrain		0.1990	0.0202		0.1746	0.0000	0.0041				
Bioretention	Pond + Media	2.7393	2.7393	0.0078	2.1890	0.5426	0.0000	0.0000	2.4792	0.2178	8.0%	7.3%
	Underdrain		2.1890	0.2100		1.9367	0.0000	0.0423				
Total		2.9821		0.2388			0.0000	0.0464	2.6969	0.2388		8.0%

total rainfall (in)	31.205
drainage area (ac)	5.198
overall runoff coeff	0.221

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	69,198	69,198	7,243	59,598	2,358	0	0	34,104	34,966	50.5%	2.6%
	Underdrain		59,598	27,717		31,746	0	128				
Bioretention	Pond + Media	1,283,549	1,283,549	152,001	1,068,950	62,599	0	0	644,533	636,710	49.6%	47.1%
	Underdrain		1,068,950	484,603		581,935	0	2,306				
Total		1,352,748		671,564			0	2,434	678,638	671,676		49.7%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.4510	0.4510	0.0075	0.4339	0.0096	0.0000	0.0000	0.2858	0.1559	34.6%	3.1%
	Underdrain		0.4339	0.1483		0.2762	0.0000	0.0093				
Bioretention	Pond + Media	4.5040	4.5040	0.0884	4.2400	0.1756	0.0000	0.0000	2.9316	1.4823	32.9%	29.9%
	Underdrain		4.2400	1.3931		2.7561	0.0000	0.0901				
Total		4.9550		1.6373			0.0000	0.0994	3.2175	1.6381		33.1%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2026	0.2026	0.0208	0.1516	0.0301	0.0000	0.0000	0.1216	0.0805	39.7%	3.0%
	Underdrain		0.1516	0.0597		0.0915	0.0000	0.0004				
Bioretention	Pond + Media	2.4561	2.4561	0.2681	1.8056	0.3824	0.0000	0.0000	1.4736	0.9774	39.8%	36.8%
	Underdrain		1.8056	0.7091		1.0913	0.0000	0.0051				
Total		2.6587		1.0577			0.0000	0.0055	1.5953	1.0579		39.8%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.3345	0.3345	0.0240	0.2780	0.0325	0.0000	0.0000	0.2008	0.1322	39.5%	3.1%
	Underdrain		0.2780	0.1081		0.1683	0.0000	0.0015				
Bioretention	Pond + Media	3.9873	3.9873	0.3108	3.2538	0.4226	0.0000	0.0000	2.4173	1.5518	38.9%	35.9%
	Underdrain		3.2538	1.2405		1.9946	0.0000	0.0182				
Total		4.3218		1.6834			0.0000	0.0197	2.6181	1.6840		39.0%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.1436	0.1436	0.0028	0.1378	0.0031	0.0000	0.0000	0.0897	0.0514	35.8%	2.9%
	Underdrain		0.1378	0.0486		0.0866	0.0000	0.0026				
Bioretention	Pond + Media	1.6421	1.6421	0.0374	1.5460	0.0587	0.0000	0.0000	1.0512	0.5628	34.3%	31.5%
	Underdrain		1.5460	0.5252		0.9925	0.0000	0.0280				
Total		1.7857		0.6140			0.0000	0.0306	1.1409	0.6142		34.4%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0571	0.0571	0.0011	0.0546	0.0014	0.0000	0.0000	0.0357	0.0204	35.7%	2.8%
	Underdrain		0.0546	0.0192		0.0343	0.0000	0.0010				
Bioretention	Pond + Media	0.6679	0.6679	0.0154	0.6194	0.0331	0.0000	0.0000	0.4319	0.2247	33.6%	31.0%
	Underdrain		0.6194	0.2092		0.3989	0.0000	0.0113				
Total		0.7249		0.2449			0.0000	0.0123	0.4676	0.2450		33.8%

Table I-8 2010 Flows and Loads of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.3259	0.3259	0.0014	0.2714	0.0531	0.0000	0.0000	0.2993	0.0297	9.0%	0.7%
	Underdrain		0.2714	0.0283		0.2461	0.0041	0.0011				
Bioretention	Pond + Media	3.6717	3.6717	0.0120	2.8344	0.8253	0.0000	0.0000	3.3976	0.3039	8.2%	7.5%
	Underdrain		2.8344	0.2918		2.5723	0.0423	0.0126				
Total		3.9976		0.3335			0.0464	0.0137	3.6968	0.3335		8.2%

total rainfall (in)	37.961
drainage area (ac)	5.198
overall runoff coeff	0.243

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	79,448	79,448	14,396	59,781	5,270	0	0	39,910	38,139	47.9%	2.5%
	Underdrain		59,781	23,749		34,640	128	1,527				
Bioretention	Pond + Media	1,470,164	1,470,164	245,765	1,045,455	178,945	0	0	786,827	684,489	46.5%	44.1%
	Underdrain		1,045,455	438,780		607,882	2,306	1,154				
Total		1,549,612		722,690			2,434	2,681	826,737	722,628		46.6%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.4865	0.4865	0.0167	0.4421	0.0278	0.0000	0.0000	0.3402	0.1408	28.4%	2.6%
	Underdrain		0.4421	0.1242		0.3125	0.0093	0.0149				
Bioretention	Pond + Media	4.8511	4.8511	0.1538	4.1653	0.5320	0.0000	0.0000	3.4864	1.3710	27.7%	25.2%
	Underdrain		4.1653	1.2172		2.9544	0.0901	0.0838				
Total		5.3376		1.5118			0.0994	0.0987	3.8266	1.5117		27.8%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2480	0.2480	0.0427	0.1689	0.0365	0.0000	0.0000	0.1438	0.1016	40.9%	3.2%
	Underdrain		0.1689	0.0590		0.1073	0.0004	0.0030				
Bioretention	Pond + Media	2.9324	2.9324	0.4444	1.8898	0.5982	0.0000	0.0000	1.7988	1.1360	38.7%	35.7%
	Underdrain		1.8898	0.6917		1.2006	0.0051	0.0027				
Total		3.1804		1.2377			0.0055	0.0058	1.9426	1.2376		38.8%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.3831	0.3831	0.0481	0.2932	0.0417	0.0000	0.0000	0.2334	0.1441	37.5%	2.9%
	Underdrain		0.2932	0.0961		0.1917	0.0015	0.0070				
Bioretention	Pond + Media	4.5442	4.5442	0.5119	3.2995	0.7329	0.0000	0.0000	2.8822	1.6676	36.5%	33.7%
	Underdrain		3.2995	1.1558		2.1494	0.0182	0.0126				
Total		4.9273		1.8119			0.0197	0.0197	3.1156	1.8117		36.6%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.1547	0.1547	0.0059	0.1400	0.0087	0.0000	0.0000	0.1057	0.0472	30.0%	2.4%
	Underdrain		0.1400	0.0413		0.0970	0.0026	0.0044				
Bioretention	Pond + Media	1.7688	1.7688	0.0628	1.5209	0.1852	0.0000	0.0000	1.2423	0.5291	29.4%	27.1%
	Underdrain		1.5209	0.4664		1.0571	0.0280	0.0254				
Total		1.9235		0.5764			0.0306	0.0298	1.3480	0.5763		29.5%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.0616	0.0616	0.0024	0.0556	0.0037	0.0000	0.0000	0.0422	0.0187	29.8%	2.3%
	Underdrain		0.0556	0.0163		0.0385	0.0010	0.0017				
Bioretention	Pond + Media	0.7216	0.7216	0.0260	0.6129	0.0827	0.0000	0.0000	0.5098	0.2129	29.0%	26.8%
	Underdrain		0.6129	0.1869		0.4271	0.0113	0.0102				
Total		0.7833		0.2316			0.0123	0.0120	0.5520	0.2316		29.1%

Table I-9 2007-2010 Flows and Loads of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	1.0392	1.0392	0.0040	0.8889	0.1463	0.0000	0.0000	0.9344	0.1037	10.0%	0.8%
	Underdrain		0.8889	0.0997		0.7881	0.0000	0.0011				
Bioretention	Pond + Media	11.7390	11.7390	0.0374	9.5490	2.1526	0.0000	0.0000	10.6573	1.0691	9.1%	8.4%
	Underdrain		9.5490	1.0317		8.5047	0.0000	0.0126				
Total		12.7783		1.1728			0.0000	0.0137	11.5918	1.1728		9.2%

total rainfall (in)	131.314
drainage area (ac)	5.198
overall runoff coeff	0.225

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	287,747	287,747	36,668	238,190	12,889	0	0	138,855	147,366	51.2%	2.6%
	Underdrain		238,190	110,698		125,966	0	1,527				
Bioretention	Pond + Media	5,362,557	5,362,557	676,352	4,250,042	436,167	0	0	2,727,194	2,634,209	49.1%	46.6%
	Underdrain		4,250,042	1,957,807		2,291,027	0	1,154				
Total		5,650,304		2,781,525			0	2,681	2,866,049	2,781,575		49.2%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	1.8627	1.8627	0.0415	1.7563	0.0649	0.0000	0.0000	1.2281	0.6197	33.3%	3.0%
	Underdrain		1.7563	0.5782		1.1632	0.0000	0.0149				
Bioretention	Pond + Media	18.7471	18.7471	0.4209	17.0074	1.3188	0.0000	0.0000	12.7637	5.8996	31.5%	28.6%
	Underdrain		17.0074	5.4780		11.4449	0.0000	0.0838				
Total		20.6098		6.5186			0.0000	0.0987	13.9918	6.5193		31.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.8561	0.8561	0.1078	0.6483	0.1000	0.0000	0.0000	0.4876	0.3655	42.7%	3.3%
	Underdrain		0.6483	0.2577		0.3876	0.0000	0.0030				
Bioretention	Pond + Media	10.3544	10.3544	1.2150	7.5832	1.5563	0.0000	0.0000	6.1038	4.2479	41.0%	37.9%
	Underdrain		7.5832	3.0329		4.5475	0.0000	0.0027				
Total		11.2105		4.6133			0.0000	0.0058	6.5914	4.6134		41.2%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	1.3901	1.3901	0.1239	1.1484	0.1177	0.0000	0.0000	0.8150	0.5680	40.9%	3.2%
	Underdrain		1.1484	0.4441		0.6973	0.0000	0.0070				
Bioretention	Pond + Media	16.5640	16.5640	1.4133	13.2165	1.9342	0.0000	0.0000	10.0235	6.5279	39.4%	36.4%
	Underdrain		13.2165	5.1142		8.0893	0.0000	0.0126				
Total		17.9541		7.0955			0.0000	0.0197	10.8385	7.0959		39.5%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.5950	0.5950	0.0151	0.5593	0.0206	0.0000	0.0000	0.3847	0.2059	34.6%	2.8%
	Underdrain		0.5593	0.1908		0.3642	0.0000	0.0044				
Bioretention	Pond + Media	6.8456	6.8456	0.1750	6.2155	0.4552	0.0000	0.0000	4.5689	2.2513	32.9%	30.3%
	Underdrain		6.2155	2.0761		4.1137	0.0000	0.0254				
Total		7.4406		2.4570			0.0000	0.0298	4.9536	2.4572		33.0%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioswale	Pond + Media	0.2381	0.2381	0.0061	0.2233	0.0088	0.0000	0.0000	0.1543	0.0821	34.5%	2.7%
	Underdrain		0.2233	0.0760		0.1455	0.0000	0.0017				
Bioretention	Pond + Media	2.8269	2.8269	0.0745	2.5299	0.2225	0.0000	0.0000	1.9055	0.9112	32.2%	29.7%
	Underdrain		2.5299	0.8366		1.6830	0.0000	0.0102				
Total		3.0650		0.9932			0.0000	0.0120	2.0598	0.9933		32.4%

Table I-10 Summary of Flow and Load Removed of Subbasin 310 BMP Performance Evaluation Modeling

FLOW

BMP	Flow removed (ac-ft)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.0320	0.0210	0.0210	0.0297	0.1037	8.2%	25.5%	8.7%	9.0%	10.0%	0.7%	2.1%	0.7%	0.7%	0.8%
Bioretention	0.3280	0.2195	0.2178	0.3039	1.0691	7.4%	23.7%	8.0%	8.2%	9.1%	6.8%	21.8%	7.3%	7.5%	8.4%
Total	0.3600	0.2405	0.2388	0.3335	1.1728						7.5%	23.9%	8.0%	8.2%	9.2%

BACT

BMP	Load removed (10^6)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	52,461	21,800	34,966	38,139	147,366	50.9%	60.4%	50.5%	47.9%	51.2%	2.6%	3.1%	2.6%	2.5%	2.6%
Bioretention	926,974	386,035	636,710	684,489	2,634,209	47.5%	58.5%	49.6%	46.5%	49.1%	45.2%	55.5%	47.1%	44.1%	46.6%
Total	979,436	407,835	671,676	722,628	2,781,575						47.7%	58.6%	49.7%	46.6%	49.2%

ORGN

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.2136	0.1095	0.1559	0.1408	0.6197	31.3%	44.9%	34.6%	28.4%	33.3%	2.8%	4.2%	3.1%	2.6%	3.0%
Bioretention	2.0267	1.0196	1.4823	1.3710	5.8996	28.9%	42.9%	32.9%	27.7%	31.5%	26.3%	38.9%	29.9%	25.2%	28.6%
Total	2.2403	1.1291	1.6381	1.5117	6.5193						29.1%	43.1%	33.1%	27.8%	31.6%

NH3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.1390	0.0443	0.0805	0.1016	0.3655	43.0%	53.8%	39.7%	40.9%	42.7%	3.3%	3.9%	3.0%	3.2%	3.3%
Bioretention	1.5897	0.5449	0.9774	1.1360	4.2479	40.6%	52.1%	39.8%	38.7%	41.0%	37.5%	48.3%	36.8%	35.7%	37.9%
Total	1.7287	0.5892	1.0579	1.2376	4.6134						40.7%	52.2%	39.8%	38.8%	41.2%

NO3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.2096	0.0821	0.1322	0.1441	0.5680	40.6%	52.6%	39.5%	37.5%	40.9%	3.1%	4.0%	3.1%	2.9%	3.2%
Bioretention	2.3529	0.9556	1.5518	1.6676	6.5279	38.2%	51.0%	38.9%	36.5%	39.4%	35.3%	47.1%	35.9%	33.7%	36.4%
Total	2.5625	1.0377	1.6840	1.8117	7.0959						38.4%	51.1%	39.0%	36.6%	39.5%

ORGP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.0722	0.0350	0.0514	0.0472	0.2059	32.8%	45.7%	35.8%	30.0%	34.6%	2.6%	3.7%	2.9%	2.4%	2.8%
Bioretention	0.7847	0.3747	0.5628	0.5291	2.2513	30.5%	43.6%	34.3%	29.4%	32.9%	28.1%	40.1%	31.5%	27.1%	30.3%
Total	0.8569	0.4098	0.6142	0.5763	2.4572						30.6%	43.8%	34.4%	29.5%	33.0%

ORTHOP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioswale	0.0291	0.0139	0.0204	0.0187	0.0821	32.7%	45.9%	35.7%	29.8%	34.5%	2.5%	3.8%	2.8%	2.3%	2.7%
Bioretention	0.3247	0.1489	0.2247	0.2129	0.9112	29.6%	43.8%	33.6%	29.0%	32.2%	27.4%	40.2%	31.0%	26.8%	29.7%
Total	0.3538	0.1628	0.2450	0.2316	0.9933						29.8%	44.0%	33.8%	29.1%	32.4%

J. Subbasin 330 BMP Performance Evaluation Modeling

Site Description and Land uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 330 is at the Pin Oak II Apartments between Oaklawn Dr and Pin Oak Dr as shown in Exhibit J-1.

Following evaluation of site conditions and discussion with the River Authority, two bioretention areas were proposed (Bioretention N and Bioretention S) as shown in Exhibits J-1 and J-2. Based on the size classification in the BMP Tool Database, both were considered "average."

The drainage area to each bioretention was delineated using Arc Hydro and the DEM data provided by the River Authority. The areas were determined to be 1.187 acres for Bioretention N and 0.995 acre for Bioretention S. As shown in Exhibit J-1, the land use in the delineated drainage area includes mostly multi-family residential and commercial.

The land uses and their corresponding impervious cover percentages from the 2017 land use data provided by the River Authority are used to determine the pervious (Per.) and impervious (Imp.) areas within the delineated drainage areas, as listed in Table J-1.

Table J-1 Land uses of Subbasin 330 BMP Sites

Land use	IC%	Bioretention N			IC%	Bioretention S		
		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)
Residential Multi-family	75	0.219	0.658	0.877	75	0.114	0.343	0.457
Commercial	90	0.031	0.279	0.310	90	0.054	0.484	0.538
TOTAL	78.9	0.250	0.937	1.187	83.1	0.168	0.827	0.995

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQVs for the selected BMP sites are:
1.5"/12 x 0.6 x 0.937 ac x 1.2 = 0.084 ac-ft for Bioretention N
1.5"/12 x 0.6 x 0.827 ac x 1.2 = 0.074 ac-ft for Bioretention S

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority's LID Manual (SARA, 2019; page B-117). The water quality volume and surface area of each BMP are shown in Table J-2.

Table J-2 Water Quality Volume and Surface Area of Subbasin 330 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioretention N	0.0982	0.0505
Bioretention S	0.0882	0.0487
Total	0.1864	
Required	0.1580	

Note: Surface area is the area at the water level of the WQV.

Exhibit J-1 Delineated Drainage Area to Subbasin 330 BMP Site

Exhibit J-2 Proposed BMP Layout on Subbasin 330 Site

Modeling Bioretention in HSPF

Refer to the discussion in Section F. As in the other cases, Bioretention S is on Type D soil. However, Bioretention N is on Type C soil. An infiltration rate of 0.1 in/hr (USACE, 2000) was assumed for the underlying soil of Bioretention N. This 0.1 in/hr refers to the infiltration rate of the underlying HSG Type C soil beneath the underdrain. The Hydrologic Modeling System-Hydrologic Engineering Center (HEC-HMS) Technical Manual indicates that for Type C soil, infiltration rate is 0.05-0.15 in/hr. Therefore, a 0.1 in/hr infiltration rate was selected for the underlying Type C soil.

Note that a 1.5 in/hr infiltration rate was selected for infiltration through the bioretention soil media above the underdrain. The River Authority's LID Manual indicates that this infiltration rate should range from 1 to 6 in/hr, and the recommended rate is 1-2 in/hr (see page B-36 of the Manual). Therefore, a 1.5 in/hr infiltration rate was selected for the bioretention soil media above the underdrain.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table J-3 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

Table J-3 EC Concentrations of Subbasin 310 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioretention N	73,941	14,747	16,202	13,835
Bioretention S	61,555	12,148	10,914	12,141
Overall	68,134	13,530	11,508	13,036

Tables J-4 to J-7 list the model output annual inflows and outflows of the bioretention in Subbasin 330 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed, and the corresponding removal percentages (or BMP performance) are also listed. Table J-8 shows the same set of information but for the 4-year total.

The constituent removal percentages were calculated in two approaches – based on individual input to a BMP and based on the total input coming from the total drainage area. The loads removed and removal percentages calculated are summarized in Table J-9 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

The two BMPs are similar in design. The higher removal percentages of Bioretention N are the result of water and constituents removed due to infiltration.

Table J-4 2007 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.5030	2.5030	0.0087	2.0479	0.4465	0.0000	0.0000	1.7210	0.7820	31.2%	16.6%
	Underdrain		2.0479	0.0487	0.7246	1.2745	0.0000	0.0000				
Bioretention S	Pond + Media	2.2100	2.2100	0.0079	1.8173	0.3849	0.0000	0.0000	2.0468	0.1602	7.3%	3.4%
	Underdrain		1.8173	0.1524		1.6619	0.0000	0.0030				
Total		4.7131		0.2176			0.0000	0.0030	3.7678	0.9423		20.0%

total rainfall (in)	47.927
drainage area (ac)	2.184
overall runoff coeff	0.540

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1,091,300	1,091,300	129,170	859,907	102,223	0	0	427,249	664,051	60.8%	35.1%
	Underdrain		859,907	331,391	203,490	325,026	0	0				
Bioretention S	Pond + Media	800,363	800,363	96,386	631,875	72,100	0	0	417,281	383,081	47.9%	20.3%
	Underdrain		631,875	286,694		345,182	0	0				
Total		1,891,662		843,639			0	0	844,530	1,047,132		55.4%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	4.4228	4.4228	0.0934	3.9987	0.3307	0.0000	0.0000	2.1502	2.2726	51.4%	27.3%
	Underdrain		3.9987	0.4555	1.7238	1.8195	0.0000	0.0000				
Bioretention S	Pond + Media	3.9003	3.9003	0.0838	3.5368	0.2797	0.0000	0.0000	2.7625	1.1370	29.2%	13.7%
	Underdrain		3.5368	1.0532		2.4828	0.0000	0.0008				
Total		8.3231		1.6859			0.0000	0.0008	4.9126	3.4096		41.0%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.2736	2.2736	0.2506	1.6979	0.3252	0.0000	0.0000	1.0834	1.1903	52.4%	27.8%
	Underdrain		1.6979	0.5610	0.3787	0.7582	0.0000	0.0000				
Bioretention S	Pond + Media	2.0069	2.0069	0.2253	1.5022	0.2794	0.0000	0.0000	1.1876	0.8193	40.8%	19.1%
	Underdrain		1.5022	0.5940		0.9081	0.0000	0.0000				
Total		4.2805		1.6309			0.0000	0.0000	2.2709	2.0096		46.9%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.5861	3.5861	0.2958	2.8395	0.4508	0.0000	0.0000	1.7342	1.8519	51.6%	27.4%
	Underdrain		2.8395	0.7822	0.7739	1.2834	0.0000	0.0000				
Bioretention S	Pond + Media	3.1664	3.1664	0.2662	2.5139	0.3863	0.0000	0.0000	1.9576	1.2088	38.2%	17.9%
	Underdrain		2.5139	0.9426		1.5713	0.0000	0.0000				
Total		6.7525		2.2868			0.0000	0.0000	3.6918	3.0607		45.3%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.4184	1.4184	0.0341	1.2810	0.1034	0.0000	0.0000	0.6785	0.7398	52.2%	27.7%
	Underdrain		1.2810	0.1673	0.5385	0.5752	0.0000	0.0000				
Bioretention S	Pond + Media	1.2510	1.2510	0.0306	1.1329	0.0875	0.0000	0.0000	0.8682	0.3826	30.6%	14.3%
	Underdrain		1.1329	0.3521		0.7807	0.0000	0.0001				
Total		2.6693		0.5840			0.0000	0.0001	1.5467	1.1225		42.1%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.5736	0.5736	0.0140	0.5171	0.0425	0.0000	0.0000	0.2766	0.2970	51.8%	27.5%
	Underdrain		0.5171	0.0671	0.2160	0.2341	0.0000	0.0000				
Bioretention S	Pond + Media	0.5050	0.5050	0.0125	0.4568	0.0357	0.0000	0.0000	0.3511	0.1538	30.5%	14.3%
	Underdrain		0.4568	0.1413		0.3154	0.0000	0.0001				
Total		1.0786		0.2349			0.0000	0.0001	0.6277	0.4508		41.8%

Table J-5 2008 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.5286	0.5286	0.0013	0.5219	0.0054	0.0000	0.0000	0.2854	0.2432	46.0%	24.4%
	Underdrain		0.5219	0.0182	0.2237	0.2800	0.0000	0.0000				
Bioretention S	Pond + Media	0.4669	0.4669	0.0012	0.4625	0.0033	0.0000	0.0000	0.3620	0.1079	23.0%	10.8%
	Underdrain		0.4625	0.1067		0.3587	0.0030	0.0000				
Total		0.9956		0.1274			0.0030	0.0000	0.6475	0.3511		35.2%

total rainfall (in)	14.221
drainage area (ac)	2.184
overall runoff coeff	0.385

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	383,495	383,495	29,140	351,570	2,785	0	0	109,518	273,976	71.4%	41.2%
	Underdrain		351,570	133,767	111,069	106,734	0	0				
Bioretention S	Pond + Media	281,492	281,492	21,792	258,306	1,394	0	0	118,938	162,555	57.7%	24.4%
	Underdrain		258,306	140,763		117,544	0	0				
Total		664,987		325,463			0	0	228,456	436,531		65.6%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.5760	1.5760	0.0194	1.5472	0.0094	0.0000	0.0000	0.5363	1.0397	66.0%	35.0%
	Underdrain		1.5472	0.1723	0.8480	0.5269	0.0000	0.0000				
Bioretention S	Pond + Media	1.3920	1.3920	0.0175	1.3689	0.0056	0.0000	0.0000	0.8123	0.5805	41.7%	19.6%
	Underdrain		1.3689	0.5630		0.8067	0.0008	0.0000				
Total		2.9680		0.7723			0.0008	0.0000	1.3486	1.6203		54.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.6347	0.6347	0.0436	0.5872	0.0039	0.0000	0.0000	0.2198	0.4149	65.4%	34.7%
	Underdrain		0.5872	0.1962	0.1750	0.2159	0.0000	0.0000				
Bioretention S	Pond + Media	0.5606	0.5606	0.0391	0.5191	0.0023	0.0000	0.0000	0.2731	0.2875	51.3%	24.1%
	Underdrain		0.5191	0.2483		0.2708	0.0000	0.0000				
Total		1.1953		0.5273			0.0000	0.0000	0.4929	0.7024		58.8%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.1110	1.1110	0.0561	1.0471	0.0079	0.0000	0.0000	0.3771	0.7339	66.1%	35.1%
	Underdrain		1.0471	0.2888	0.3891	0.3692	0.0000	0.0000				
Bioretention S	Pond + Media	0.9813	0.9813	0.0505	0.9261	0.0047	0.0000	0.0000	0.4886	0.4927	50.2%	23.5%
	Underdrain		0.9261	0.4423		0.4838	0.0000	0.0000				
Total		2.0923		0.8376			0.0000	0.0000	0.8656	1.2267		58.6%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.4925	0.4925	0.0074	0.4821	0.0030	0.0000	0.0000	0.1719	0.3206	65.1%	34.6%
	Underdrain		0.4821	0.0609	0.2523	0.1689	0.0000	0.0000				
Bioretention S	Pond + Media	0.4350	0.4350	0.0067	0.4265	0.0018	0.0000	0.0000	0.2500	0.1852	42.6%	20.0%
	Underdrain		0.4265	0.1785		0.2482	0.0001	0.0000				
Total		0.9276		0.2535			0.0001	0.0000	0.4219	0.5058		54.5%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.1950	0.1950	0.0029	0.1909	0.0012	0.0000	0.0000	0.0675	0.1275	65.4%	34.7%
	Underdrain		0.1909	0.0241	0.1005	0.0663	0.0000	0.0000				
Bioretention S	Pond + Media	0.1722	0.1722	0.0026	0.1689	0.0007	0.0000	0.0000	0.0987	0.0736	42.7%	20.0%
	Underdrain		0.1689	0.0710		0.0980	0.0001	0.0000				
Total		0.3672		0.1006			0.0001	0.0000	0.1662	0.2011		54.7%

Table J-6 2009 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.5643	1.5643	0.0044	1.2485	0.3114	0.0000	0.0000	1.1015	0.4628	29.6%	15.7%
	Underdrain		1.2485	0.0213	0.4371	0.7901	0.0000	0.0000				
Bioretention S	Pond + Media	1.3815	1.3815	0.0040	1.1055	0.2719	0.0000	0.0000	1.2543	0.1066	7.7%	3.6%
	Underdrain		1.1055	0.1026		0.9823	0.0000	0.0206				
Total		2.9458		0.1323			0.0000	0.0206	2.3558	0.5694		19.3%

total rainfall (in)	31.205
drainage area (ac)	2.184
overall runoff coeff	0.519

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	733,403	733,403	91,602	609,834	31,965	0	0	265,856	467,547	63.8%	36.8%
	Underdrain		609,834	215,835	160,108	233,891	0	0				
Bioretention S	Pond + Media	538,124	538,124	67,818	447,690	22,616	0	0	268,008	269,138	50.0%	21.2%
	Underdrain		447,690	201,274		245,393	0	978				
Total		1,271,527		576,529			0	978	533,864	736,685		57.9%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.9220	2.9220	0.0606	2.7774	0.0839	0.0000	0.0000	1.3171	1.6049	54.9%	29.2%
	Underdrain		2.7774	0.2872	1.2571	1.2332	0.0000	0.0000				
Bioretention S	Pond + Media	2.5789	2.5789	0.0541	2.4545	0.0703	0.0000	0.0000	1.6751	0.8520	33.0%	15.5%
	Underdrain		2.4545	0.7975		1.6048	0.0000	0.0518				
Total		5.5009		1.1994			0.0000	0.0518	2.9922	2.4569		44.7%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.4455	1.4455	0.1651	1.0638	0.2166	0.0000	0.0000	0.6964	0.7491	51.8%	27.5%
	Underdrain		1.0638	0.3179	0.2661	0.4798	0.0000	0.0000				
Bioretention S	Pond + Media	1.2765	1.2765	0.1473	0.9401	0.1891	0.0000	0.0000	0.7577	0.5161	40.4%	19.0%
	Underdrain		0.9401	0.3687		0.5687	0.0000	0.0026				
Total		2.7220		0.9990			0.0000	0.0026	1.4541	1.2652		46.5%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.3421	2.3421	0.1916	1.9049	0.2457	0.0000	0.0000	1.1021	1.2400	52.9%	28.1%
	Underdrain		1.9049	0.4761	0.5724	0.8564	0.0000	0.0000				
Bioretention S	Pond + Media	2.0685	2.0685	0.1711	1.6840	0.2134	0.0000	0.0000	1.2517	0.8072	39.0%	18.3%
	Underdrain		1.6840	0.6358		1.0384	0.0000	0.0095				
Total		4.4106		1.4746			0.0000	0.0095	2.3539	2.0472		46.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.9245	0.9245	0.0223	0.8756	0.0266	0.0000	0.0000	0.4141	0.5105	55.2%	29.3%
	Underdrain		0.8756	0.1032	0.3850	0.3875	0.0000	0.0000				
Bioretention S	Pond + Media	0.8161	0.8161	0.0199	0.7738	0.0224	0.0000	0.0000	0.5223	0.2797	34.3%	16.1%
	Underdrain		0.7738	0.2596		0.4999	0.0000	0.0141				
Total		1.7406		0.4050			0.0000	0.0141	0.9364	0.7902		45.4%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.3666	0.3666	0.0089	0.3466	0.0112	0.0000	0.0000	0.1645	0.2022	55.1%	29.3%
	Underdrain		0.3466	0.0408	0.1525	0.1533	0.0000	0.0000				
Bioretention S	Pond + Media	0.3233	0.3233	0.0079	0.3062	0.0093	0.0000	0.0000	0.2071	0.1106	34.2%	16.0%
	Underdrain		0.3062	0.1027		0.1978	0.0000	0.0056				
Total		0.6900		0.1602			0.0000	0.0056	0.3715	0.3128		45.3%

Table J-7 2010 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.0985	2.0985	0.0070	1.6031	0.4884	0.0000	0.0000	1.5849	0.5135	24.5%	12.9%
	Underdrain		1.6031	0.0274	0.4791	1.0965	0.0000	0.0000				
Bioretention S	Pond + Media	1.8532	1.8532	0.0064	1.4228	0.4240	0.0000	0.0000	1.7187	0.1487	7.9%	3.7%
	Underdrain		1.4228	0.1423		1.2947	0.0206	0.0064				
Total		3.9517		0.1831			0.0206	0.0064	3.3037	0.6622		16.7%

total rainfall (in)	37.961
drainage area (ac)	2.184
overall runoff coeff	0.572

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	840,421	840,421	142,637	592,292	105,490	0	0	356,979	483,443	57.5%	33.2%
	Underdrain		592,292	194,759	146,039	251,489	0	0				
Bioretention S	Pond + Media	616,657	616,657	106,539	435,539	74,580	0	0	328,874	288,303	46.7%	19.8%
	Underdrain		435,539	181,788		254,294	978	458				
Total		1,457,079		625,723			978	458	685,853	771,745		52.9%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.1451	3.1451	0.1013	2.7015	0.3423	0.0000	0.0000	1.6691	1.4760	46.9%	24.7%
	Underdrain		2.7015	0.2482	1.1264	1.3268	0.0000	0.0000				
Bioretention S	Pond + Media	2.7760	2.7760	0.0912	2.3936	0.2911	0.0000	0.0000	1.9951	0.7849	27.8%	13.1%
	Underdrain		2.3936	0.6936		1.7040	0.0518	0.0478				
Total		5.9211		1.1343			0.0518	0.0478	3.6642	2.2609		37.9%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.7079	1.7079	0.2613	1.0903	0.3563	0.0000	0.0000	0.8929	0.8150	47.7%	25.3%
	Underdrain		1.0903	0.3069	0.2468	0.5366	0.0000	0.0000				
Bioretention S	Pond + Media	1.5082	1.5082	0.2354	0.9653	0.3075	0.0000	0.0000	0.9234	0.5861	38.8%	18.2%
	Underdrain		0.9653	0.3507		0.6159	0.0026	0.0014				
Total		3.2161		1.1544			0.0026	0.0014	1.8162	1.4012		43.5%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	2.6639	2.6639	0.3047	1.9147	0.4445	0.0000	0.0000	1.3941	1.2698	47.7%	25.3%
	Underdrain		1.9147	0.4405	0.5246	0.9496	0.0000	0.0000				
Bioretention S	Pond + Media	2.3526	2.3526	0.2743	1.6955	0.3829	0.0000	0.0000	1.4907	0.8651	36.6%	17.2%
	Underdrain		1.6955	0.5908		1.1079	0.0095	0.0064				
Total		5.0165		1.6104			0.0095	0.0064	2.8848	2.1349		42.5%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.9938	0.9938	0.0360	0.8527	0.1050	0.0000	0.0000	0.5157	0.4781	48.1%	25.4%
	Underdrain		0.8527	0.0911	0.3509	0.4107	0.0000	0.0000				
Bioretention S	Pond + Media	0.8771	0.8771	0.0324	0.7553	0.0894	0.0000	0.0000	0.6168	0.2617	29.4%	13.9%
	Underdrain		0.7553	0.2293		0.5274	0.0141	0.0127				
Total		1.8709		0.3889			0.0141	0.0127	1.1325	0.7398		39.2%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	0.3941	0.3941	0.0144	0.3374	0.0423	0.0000	0.0000	0.2053	0.1888	47.9%	25.3%
	Underdrain		0.3374	0.0359	0.1386	0.1630	0.0000	0.0000				
Bioretention S	Pond + Media	0.3475	0.3475	0.0129	0.2987	0.0359	0.0000	0.0000	0.2446	0.1035	29.3%	13.8%
	Underdrain		0.2987	0.0905		0.2087	0.0056	0.0051				
Total		0.7417		0.1537			0.0056	0.0051	0.4500	0.2923		39.1%

Table J-8 2007-2010 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.6945	6.6945	0.0214	5.4214	1.2517	0.0000	0.0000	4.6929	2.0016	29.9%	15.9%
	Underdrain		5.4214	0.1156	1.8646	3.4412	0.0000	0.0000				
Bioretention S	Pond + Media	5.9117	5.9117	0.0195	4.8080	1.0841	0.0000	0.0000	5.3818	0.5234	8.9%	4.2%
	Underdrain		4.8080	0.5040		4.2977	0.0000	0.0064				
Total		12.6061		0.6604			0.0000	0.0064	10.0747	2.5250		20.0%

total rainfall (in)	131.314
drainage area (ac)	2.184
overall runoff coeff	0.527

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3,048,619	3,048,619	392,548	2,413,604	242,462	0	0	1,159,602	1,889,017	62.0%	35.7%
	Underdrain		2,413,604	875,752	620,706	917,140	0	0				
Bioretention S	Pond + Media	2,236,636	2,236,636	292,535	1,773,410	170,690	0	0	1,133,102	1,103,076	49.3%	20.9%
	Underdrain		1,773,410	810,518		962,412	0	458				
Total		5,285,255		2,371,354			0	458	2,292,704	2,992,093		56.6%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	12.0660	12.0660	0.2747	11.0249	0.7663	0.0000	0.0000	5.6727	6.3933	53.0%	28.1%
	Underdrain		11.0249	1.1631	4.9553	4.9063	0.0000	0.0000				
Bioretention S	Pond + Media	10.6472	10.6472	0.2467	9.7538	0.6467	0.0000	0.0000	7.2450	3.3545	31.5%	14.8%
	Underdrain		9.7538	3.1074		6.5983	0.0000	0.0478				
Total		22.7132		4.7919			0.0000	0.0478	12.9177	9.7477		42.9%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.0617	6.0617	0.7206	4.4392	0.9019	0.0000	0.0000	2.8925	3.1693	52.3%	27.8%
	Underdrain		4.4392	1.3820	1.0666	1.9905	0.0000	0.0000				
Bioretention S	Pond + Media	5.3521	5.3521	0.6471	3.9267	0.7783	0.0000	0.0000	3.1418	2.2090	41.3%	19.4%
	Underdrain		3.9267	1.5618		2.3635	0.0000	0.0014				
Total		11.4139		4.3116			0.0000	0.0014	6.0342	5.3783		47.1%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	9.7031	9.7031	0.8482	7.7061	1.1488	0.0000	0.0000	4.6074	5.0957	52.5%	27.9%
	Underdrain		7.7061	1.9876	2.2599	3.4586	0.0000	0.0000				
Bioretention S	Pond + Media	8.5689	8.5689	0.7621	6.8195	0.9873	0.0000	0.0000	5.1887	3.3738	39.4%	18.5%
	Underdrain		6.8195	2.6115		4.2014	0.0000	0.0064				
Total		18.2720		6.2094			0.0000	0.0064	9.7961	8.4695		46.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.8292	3.8292	0.0999	3.4914	0.2380	0.0000	0.0000	1.7802	2.0490	53.5%	28.4%
	Underdrain		3.4914	0.4225	1.5267	1.5422	0.0000	0.0000				
Bioretention S	Pond + Media	3.3792	3.3792	0.0896	3.0885	0.2011	0.0000	0.0000	2.2573	1.1092	32.8%	15.4%
	Underdrain		3.0885	1.0195		2.0562	0.0000	0.0127				
Total		7.2084		1.6314			0.0000	0.0127	4.0375	3.1582		43.8%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.5294	1.5294	0.0401	1.3921	0.0972	0.0000	0.0000	0.7139	0.8155	53.3%	28.3%
	Underdrain		1.3921	0.1678	0.6076	0.6166	0.0000	0.0000				
Bioretention S	Pond + Media	1.3480	1.3480	0.0359	1.2305	0.0816	0.0000	0.0000	0.9015	0.4415	32.7%	15.3%
	Underdrain		1.2305	0.4055		0.8199	0.0000	0.0051				
Total		2.8774		0.6494			0.0000	0.0051	1.6154	1.2570		43.7%

Table J-9 Summary of Flow and Load Removed of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Flow removed (ac-ft)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	0.7820	0.2432	0.4628	0.5135	2.0016	31.2%	46.0%	29.6%	24.5%	29.9%	16.6%	24.4%	15.7%	12.9%	15.9%
Bioretention S	0.1602	0.1079	0.1066	0.1487	0.5234	7.3%	23.0%	7.7%	7.9%	8.9%	3.4%	10.8%	3.6%	3.7%	4.2%
Total	0.9423	0.3511	0.5694	0.6622	2.5250						20.0%	35.2%	19.3%	16.7%	20.0%

BACT

BMP	Load removed (10^6)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	664,051	273,976	467,547	483,443	1,889,017	60.8%	71.4%	63.8%	57.5%	62.0%	35.1%	41.2%	36.8%	33.2%	35.7%
Bioretention S	383,081	162,555	269,138	288,303	1,103,076	47.9%	57.7%	50.0%	46.7%	49.3%	20.3%	24.4%	21.2%	19.8%	20.9%
Total	1,047,132	436,531	736,685	771,745	2,992,093						55.4%	65.6%	57.9%	52.9%	56.6%

ORGN

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	2.2726	1.0397	1.6049	1.4760	6.3933	51.4%	66.0%	54.9%	46.9%	53.0%	27.3%	35.0%	29.2%	24.7%	28.1%
Bioretention S	1.1370	0.5805	0.8520	0.7849	3.3545	29.2%	41.7%	33.0%	27.8%	31.5%	13.7%	19.6%	15.5%	13.1%	14.8%
Total	3.4096	1.6203	2.4569	2.2609	9.7477						41.0%	54.6%	44.7%	37.9%	42.9%

NH3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	1.1903	0.4149	0.7491	0.8150	3.1693	52.4%	65.4%	51.8%	47.7%	52.3%	27.8%	34.7%	27.5%	25.3%	27.8%
Bioretention S	0.8193	0.2875	0.5161	0.5861	2.2090	40.8%	51.3%	40.4%	38.8%	41.3%	19.1%	24.1%	19.0%	18.2%	19.4%
Total	2.0096	0.7024	1.2652	1.4012	5.3783						46.9%	58.8%	46.5%	43.5%	47.1%

NO3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	1.8519	0.7339	1.2400	1.2698	5.0957	51.6%	66.1%	52.9%	47.7%	52.5%	27.4%	35.1%	28.1%	25.3%	27.9%
Bioretention S	1.2088	0.4927	0.8072	0.8651	3.3738	38.2%	50.2%	39.0%	36.6%	39.4%	17.9%	23.5%	18.3%	17.2%	18.5%
Total	3.0607	1.2267	2.0472	2.1349	8.4695						45.3%	58.6%	46.4%	42.5%	46.4%

ORGP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	0.7398	0.3206	0.5105	0.4781	2.0490	52.2%	65.1%	55.2%	48.1%	53.5%	27.7%	34.6%	29.3%	25.4%	28.4%
Bioretention S	0.3826	0.1852	0.2797	0.2617	1.1092	30.6%	42.6%	34.3%	29.4%	32.8%	14.3%	20.0%	16.1%	13.9%	15.4%
Total	1.1225	0.5058	0.7902	0.7398	3.1582						42.1%	54.5%	45.4%	39.2%	43.8%

ORTHOP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention N	0.2970	0.1275	0.2022	0.1888	0.8155	51.8%	65.4%	55.1%	47.9%	53.3%	27.5%	34.7%	29.3%	25.3%	28.3%
Bioretention S	0.1538	0.0736	0.1106	0.1035	0.4415	30.5%	42.7%	34.2%	29.3%	32.7%	14.3%	20.0%	16.0%	13.8%	15.3%
Total	0.4508	0.2011	0.3128	0.2923	1.2570						41.8%	54.7%	45.3%	39.1%	43.7%

K. Subbasin 420 BMP Performance Evaluation Modeling

Site Description and Land uses

The site selected by the River Authority for BMP performance evaluation modeling of Subbasin 420 is the area bounded by Alazan Creek, Tampico Street and IH-35 as shown in Exhibit K-1. The San Antonio Housing Authority (SAHA) is going to build a new apartment complex at this location. After discussion between the River Authority and SAHA, SAHA agreed to consider incorporating bioretention on the site. The proposed bioretention areas and their corresponding drainage areas are superimposed on SAHA's site development plan as shown in Exhibit K-2. Bioretention W will receive the runoff from the roof of the adjacent building. Bioretention S will treat the runoff from the parking lot. The parking lot grading may need to be modified slightly so that the runoff will go to the bioretention instead of being collected by the originally proposed storm sewer line as shown in the exhibit. Moreover, it is assumed that the roof drainage of the building next to the parking lot will be connected to storm sewers instead of running on to the parking lot. Based on the size classification in the BMP Tool Database, both were considered "average."

Exhibit K-1 Selected Site for Subbasin 420

The green space in the drainage area was assumed pervious and all other areas were assumed impervious. Parameters for multi-family residential were applied in the model. The pervious (Per.) and impervious (Imp.) areas are shown in Table K-1.

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQVs for the selected BMP sites are:
1.5”/12 x 0.6 x 0.648 ac x 1.2 = 0.058 ac-ft for Bioretention W
1.5”/12 x 0.6 x 1.130 ac x 1.2 = 0.102 ac-ft for Bioretention S

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority’s LID Manual (SARA, 2019; page B-117). The water quality volume and surface area of each BMP are shown in Table K-2.

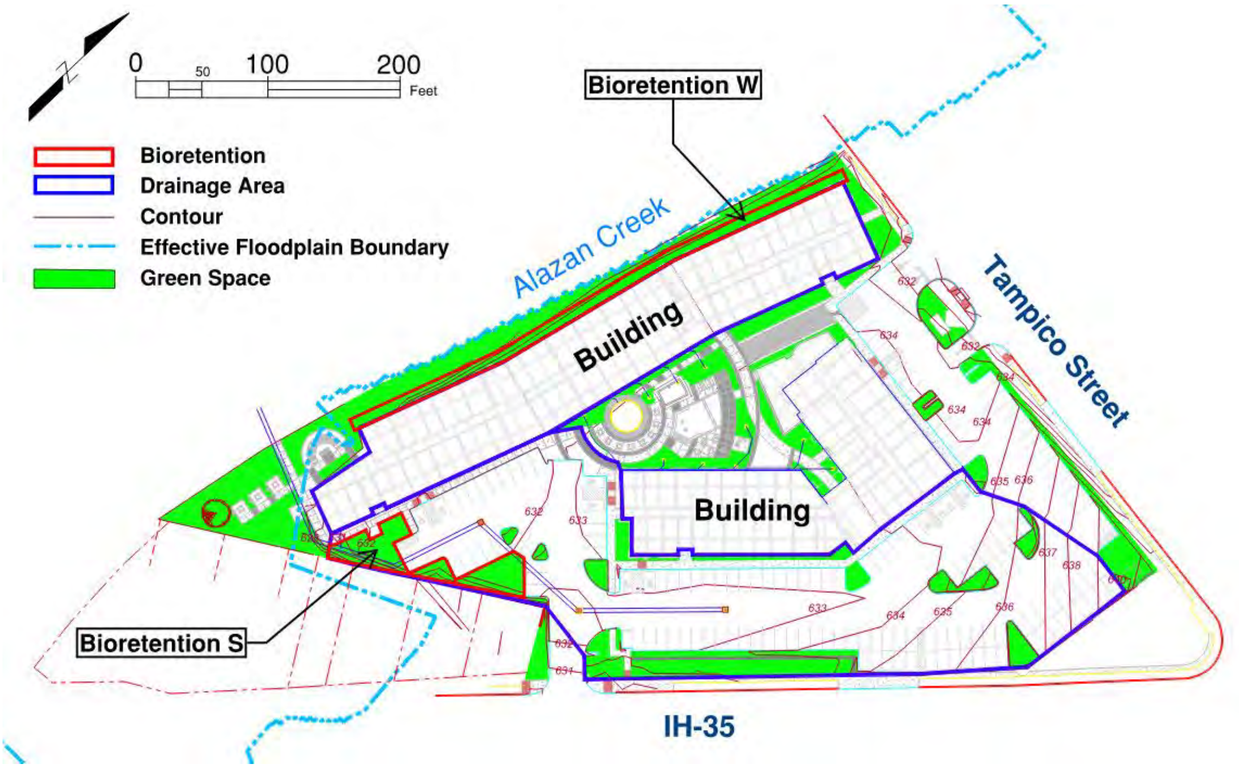


Exhibit K-2 Proposed BMP Layout on Subbasin 420 Site

Table K-1 Pervious and Impervious Areas of Subbasin 420 BMP Sites

Land use	IC%	Bioretention W			IC%	Bioretention S		
		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)		Per. Area (ac)	Imp. Area (ac)	Total Area (ac)
Residential Multi-family	100.0	0.0	0.648	0.648	82.7	0.236	1.130	1.366

Table K-2 Water Quality Volume and Surface Area of Subbasin 420 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioretention W	0.0836	0.0706
Bioretention S	0.1069	0.0581
Total	0.1905	

Required	0.1600	

Note: Surface area is the area at the water level of the WQV.

Modeling Bioretention in HSPF

Refer to the discussion in Section F, except that the soil media of Bioretention S is 4 ft deep instead of 3 ft so that sufficient WQV can be provided.

Development of HSPF Model Files

The model files were developed similar to those for Subbasin 70 described in Attachment B.

Results

The BMP performance evaluation modeling results are summarized in several tables. Table K-3 lists the inflow and outflow geometric means (Geomean) and flow-weighted Geomean of EC concentrations over the 2007 to 2010 model simulation period for the bioretention. The modeling results listed in the table show that, while the BMPs can remove EC loads from stormwater runoff, the four-year Geomean EC concentrations can still be expected to exceed the Primary Contact Recreation (PCR) Criteria of 126 #/dL, where 1 dL = 100 mL. That is, with the high EC levels in stormwater runoff, the proposed BMPs will not be sufficient to bring the outflow below the PCR Criteria.

The outflow flow-weighted geomeans are higher than the inflow. This may be better explained by following the variation of flow and EC concentration during a storm event as shown in Table K-4. In this case, apparently before the peak flow, the EC load on the land surface has already been almost completely removed and the EC concentration in the peak flow is very low. The effect of the bioretention is delaying the flow somewhat and mixing the high and low concentration water. As a result, the outflow flow-weighted geomean is higher than the inflow flow-weighted geomean even though the load is reduced by the BMP.

Table K-3 EC Concentrations of Subbasin 420 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted Geomean (#/dL)	Geomean (#/dL)	Flow-weighted Geomean (#/dL)
Bioretention W	99,882	9,178	17,862	15,549
Bioretention S	92,340	14,900	17,050	16,653
Overall	92,319	14,401	16,588	16,310

Tables K-5 to K-8 list the model output annual inflows and outflows of the bioretention in Subbasin 420 for 2007, 2008, 2009, and 2010, respectively. Each of these tables include flows, bacteria, and nutrient loads, where BACT, ORGN, NH3N, ORGP, and ORTHOP are bacteria (EC), organic nitrogen, ammonia nitrogen, organic phosphorus, and ortho-phosphate, respectively. The flows and loads removed, and the corresponding removal percentages (or BMP performance) are also listed. Table K-9 shows the same set of information but for the 4-year total.

The constituent removal percentages were calculated in two approaches – based on individual input to a BMP and based on the total input coming from the total drainage area. The loads removed and removal percentages calculated are summarized in Table K-10 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

Table K-4 Inflow and Outflow EC Concentrations of Bioretention W during Storm Event

	Inflow (cfs)	Influent EC (#/dL)	Outflow (cfs)	Effluent EC (#/dL)
8/16/2007 3:00	0.0000	0	0.0000	0
8/16/2007 4:00	0.0000	0	0.0000	0
8/16/2007 5:00	0.0584	174,957	0.0000	0
8/16/2007 6:00	0.1692	118,774	0.0000	0
8/16/2007 7:00	0.0979	73,517	0.0000	0
8/16/2007 8:00	0.0615	55,374	0.0327	79,555
8/16/2007 9:00	0.0333	46,804	0.0421	76,054
8/16/2007 10:00	0.0715	38,999	0.0421	71,140
8/16/2007 11:00	0.2836	21,698	0.0421	62,970
8/16/2007 12:00	0.5581	5,534	0.2178	26,677
8/16/2007 13:00	1.6152	311	1.5708	7,656
8/16/2007 14:00	1.5100	1	1.5098	3,195
8/16/2007 15:00	0.4345	0	0.4652	3,800
8/16/2007 16:00	0.1587	0	0.1665	6,396
8/16/2007 17:00	0.0721	0	0.0741	10,371
8/16/2007 18:00	0.0380	0	0.0426	13,818

Table K-5 2007 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	1.8314	1.8314	0.0076	1.4255	0.3983	0.0000	0.0000	1.7139	0.1175	6.4%	2.3%
	Underdrain		1.4255	0.1099		1.3156	0.0000	0.0000				
Bioretention S	Pond + Media	3.2348	3.2348	0.0101	2.2161	1.0085	0.0000	0.0000	3.0828	0.1520	4.7%	3.0%
	Underdrain		2.2161	0.1419		2.0743	0.0000	0.0000				
Total		5.0662		0.2695			0.0000	0.0000	4.7967	0.2695		5.3%

total rainfall (in)	48.295
drainage area (ac)	2.014
overall runoff coeff	0.625

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	799,159	799,159	117,012	650,561	31,586	0	0	390,386	408,773	51.2%	18.4%
	Underdrain		650,561	291,761		358,800	0	0				
Bioretention S	Pond + Media	1,416,765	1,416,765	233,327	1,023,802	159,637	0	0	764,778	651,987	46.0%	29.4%
	Underdrain		1,023,802	418,661		605,141	0	0				
Total		2,215,924		1,060,761			0	0	1,155,164	1,060,760		47.9%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2.7216	2.7216	0.0712	2.5670	0.0834	0.0000	0.0000	2.0135	0.7081	26.0%	9.4%
	Underdrain		2.5670	0.6368		1.9301	0.0000	0.0000				
Bioretention S	Pond + Media	4.8111	4.8111	0.1498	4.2048	0.4565	0.0000	0.0000	3.7791	1.0320	21.5%	13.7%
	Underdrain		4.2048	0.8823		3.3226	0.0000	0.0000				
Total		7.5327		1.7401			0.0000	0.0000	5.7926	1.7401		23.1%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	1.5353	1.5353	0.2013	1.0631	0.2709	0.0000	0.0000	0.9228	0.6125	39.9%	14.4%
	Underdrain		1.0631	0.4111		0.6520	0.0000	0.0000				
Bioretention S	Pond + Media	2.7175	2.7175	0.3768	1.6422	0.6986	0.0000	0.0000	1.7629	0.9546	35.1%	22.4%
	Underdrain		1.6422	0.5778		1.0643	0.0000	0.0000				
Total		4.2528		1.5671			0.0000	0.0000	2.6857	1.5671		36.8%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2.3959	2.3959	0.2431	1.8558	0.2970	0.0000	0.0000	1.4912	0.9047	37.8%	13.7%
	Underdrain		1.8558	0.6616		1.1942	0.0000	0.0000				
Bioretention S	Pond + Media	4.2133	4.2133	0.4644	2.8991	0.8497	0.0000	0.0000	2.8212	1.3921	33.0%	21.1%
	Underdrain		2.8991	0.9277		1.9714	0.0000	0.0000				
Total		6.6092		2.2968			0.0000	0.0000	4.3124	2.2968		34.8%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.8740	0.8740	0.0263	0.8206	0.0271	0.0000	0.0000	0.6272	0.2468	28.2%	10.2%
	Underdrain		0.8206	0.2206		0.6001	0.0000	0.0000				
Bioretention S	Pond + Media	1.5436	1.5436	0.0552	1.3446	0.1438	0.0000	0.0000	1.1797	0.3638	23.6%	15.0%
	Underdrain		1.3446	0.3087		1.0359	0.0000	0.0000				
Total		2.4176		0.6107			0.0000	0.0000	1.8069	0.6107		25.3%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.3513	0.3513	0.0105	0.3302	0.0106	0.0000	0.0000	0.2523	0.0990	28.2%	10.1%
	Underdrain		0.3302	0.0885		0.2417	0.0000	0.0000				
Bioretention S	Pond + Media	0.6311	0.6311	0.0224	0.5441	0.0646	0.0000	0.0000	0.4850	0.1461	23.2%	14.9%
	Underdrain		0.5441	0.1237		0.4204	0.0000	0.0000				
Total		0.9824		0.2451			0.0000	0.0000	0.7373	0.2451		24.9%

Table K-6 2008 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.2349	0.2349	0.0011	0.2339	0.0000	0.0000	0.0000	0.1538	0.0812	34.6%	12.6%
	Underdrain		0.2339	0.0801		0.1538	0.0000	0.0000				
Bioretention S	Pond + Media	0.4095	0.4095	0.0020	0.4075	0.0000	0.0000	0.0000	0.3017	0.1078	26.3%	16.7%
	Underdrain		0.4075	0.1058		0.3017	0.0000	0.0000				
Total		0.6444		0.1889			0.0000	0.0000	0.4555	0.1889		29.3%

total rainfall (in)	10.971
drainage area (ac)	2.014
overall runoff coeff	0.350

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	251,835	251,835	14,921	236,914	0	0	0	91,859	159,976	63.5%	23.2%
	Underdrain		236,914	145,055		91,859	0	0				
Bioretention S	Pond + Media	438,945	438,945	44,951	393,994	0	0	0	191,571	247,375	56.4%	35.8%
	Underdrain		393,994	202,424		191,571	0	0				
Total		690,780		407,352			0	0	283,430	407,351		59.0%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.8922	0.8922	0.0083	0.8839	0.0000	0.0000	0.0000	0.4349	0.4573	51.3%	18.7%
	Underdrain		0.8839	0.4490		0.4349	0.0000	0.0000				
Bioretention S	Pond + Media	1.5551	1.5551	0.0268	1.5283	0.0000	0.0000	0.0000	0.9021	0.6530	42.0%	26.7%
	Underdrain		1.5283	0.6261		0.9021	0.0000	0.0000				
Total		2.4473		1.1102			0.0000	0.0000	1.3370	1.1102		45.4%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.2932	0.2932	0.0141	0.2792	0.0000	0.0000	0.0000	0.1201	0.1731	59.0%	21.5%
	Underdrain		0.2792	0.1591		0.1201	0.0000	0.0000				
Bioretention S	Pond + Media	0.5111	0.5111	0.0434	0.4677	0.0000	0.0000	0.0000	0.2449	0.2662	52.1%	33.1%
	Underdrain		0.4677	0.2228		0.2449	0.0000	0.0000				
Total		0.8044		0.4393			0.0000	0.0000	0.3651	0.4393		54.6%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.5901	0.5901	0.0215	0.5686	0.0000	0.0000	0.0000	0.2481	0.3420	58.0%	21.1%
	Underdrain		0.5686	0.3205		0.2481	0.0000	0.0000				
Bioretention S	Pond + Media	1.0286	1.0286	0.0662	0.9624	0.0000	0.0000	0.0000	0.5172	0.5114	49.7%	31.6%
	Underdrain		0.9624	0.4452		0.5172	0.0000	0.0000				
Total		1.6187		0.8535			0.0000	0.0000	0.7653	0.8535		52.7%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.2699	0.2699	0.0030	0.2669	0.0000	0.0000	0.0000	0.1295	0.1403	52.0%	19.0%
	Underdrain		0.2669	0.1374		0.1295	0.0000	0.0000				
Bioretention S	Pond + Media	0.4704	0.4704	0.0096	0.4608	0.0000	0.0000	0.0000	0.2692	0.2011	42.8%	27.2%
	Underdrain		0.4608	0.1916		0.2692	0.0000	0.0000				
Total		0.7403		0.3415			0.0000	0.0000	0.3988	0.3415		46.1%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.1076	0.1076	0.0012	0.1064	0.0000	0.0000	0.0000	0.0515	0.0561	52.1%	19.0%
	Underdrain		0.1064	0.0549		0.0515	0.0000	0.0000				
Bioretention S	Pond + Media	0.1875	0.1875	0.0038	0.1837	0.0000	0.0000	0.0000	0.1072	0.0803	42.8%	27.2%
	Underdrain		0.1837	0.0765		0.1072	0.0000	0.0000				
Total		0.2951		0.1364			0.0000	0.0000	0.1588	0.1364		46.2%

Table K-7 2009 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.7639	0.7639	0.0030	0.7426	0.0183	0.0000	0.0000	0.6351	0.1119	14.7%	5.3%
	Underdrain		0.7426	0.1089		0.6168	0.0000	0.0169				
Bioretention S	Pond + Media	1.3315	1.3315	0.0051	1.2336	0.0928	0.0000	0.0000	1.1663	0.1438	10.8%	6.9%
	Underdrain		1.2336	0.1387		1.0735	0.0000	0.0214				
Total		2.0954		0.2557			0.0000	0.0383	1.8014	0.2557		12.2%

total rainfall (in)	25.265
drainage area (ac)	2.014
overall runoff coeff	0.494

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	659,218	659,218	72,817	577,620	8,782	0	0	278,262	380,406	57.7%	21.0%
	Underdrain		577,620	307,566		269,480	0	550				
Bioretention S	Pond + Media	1,149,077	1,149,077	175,160	929,662	44,256	0	0	534,303	613,836	53.4%	33.9%
	Underdrain		929,662	438,637		490,046	0	939				
Total		1,808,295		994,180			0	1,489	812,565	994,241		55.0%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2.2995	2.2995	0.0429	2.2334	0.0232	0.0000	0.0000	1.3296	0.9426	41.0%	14.9%
	Underdrain		2.2334	0.8994		1.3065	0.0000	0.0273				
Bioretention S	Pond + Media	4.0083	4.0083	0.1115	3.7785	0.1183	0.0000	0.0000	2.5966	1.3682	34.1%	21.7%
	Underdrain		3.7785	1.2564		2.4783	0.0000	0.0435				
Total		6.3078		2.3102			0.0000	0.0708	3.9262	2.3108		36.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.8063	0.8063	0.0843	0.7092	0.0127	0.0000	0.0000	0.3792	0.4263	52.9%	19.3%
	Underdrain		0.7092	0.3419		0.3665	0.0000	0.0008				
Bioretention S	Pond + Media	1.4053	1.4053	0.1966	1.1402	0.0685	0.0000	0.0000	0.7239	0.6800	48.4%	30.7%
	Underdrain		1.1402	0.4833		0.6554	0.0000	0.0014				
Total		2.2116		1.1062			0.0000	0.0023	1.1031	1.1063		50.0%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	1.5642	1.5642	0.1175	1.4243	0.0224	0.0000	0.0000	0.7723	0.7888	50.4%	18.4%
	Underdrain		1.4243	0.6712		0.7499	0.0000	0.0031				
Bioretention S	Pond + Media	2.7265	2.7265	0.2820	2.3269	0.1175	0.0000	0.0000	1.4931	1.2280	45.0%	28.6%
	Underdrain		2.3269	0.9459		1.3756	0.0000	0.0053				
Total		4.2907		2.0166			0.0000	0.0085	2.2655	2.0168		47.0%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.7205	0.7205	0.0157	0.6974	0.0074	0.0000	0.0000	0.4080	0.3051	42.3%	15.4%
	Underdrain		0.6974	0.2893		0.4005	0.0000	0.0075				
Bioretention S	Pond + Media	1.2560	1.2560	0.0405	1.1769	0.0386	0.0000	0.0000	0.7957	0.4482	35.7%	22.7%
	Underdrain		1.1769	0.4076		0.7571	0.0000	0.0121				
Total		1.9765		0.7531			0.0000	0.0196	1.2037	0.7532		38.1%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.2853	0.2853	0.0062	0.2762	0.0029	0.0000	0.0000	0.1615	0.1209	42.4%	15.4%
	Underdrain		0.2762	0.1147		0.1585	0.0000	0.0030				
Bioretention S	Pond + Media	0.4974	0.4974	0.0160	0.4662	0.0152	0.0000	0.0000	0.3152	0.1775	35.7%	22.7%
	Underdrain		0.4662	0.1614		0.3000	0.0000	0.0048				
Total		0.7827		0.2983			0.0000	0.0077	0.4766	0.2984		38.1%

Table K-8 2010 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.9855	0.9855	0.0032	0.7863	0.1960	0.0000	0.0000	0.8931	0.0981	9.8%	3.6%
	Underdrain		0.7863	0.0949		0.6971	0.0169	0.0112				
Bioretention S	Pond + Media	1.7179	1.7179	0.0041	1.2367	0.4771	0.0000	0.0000	1.5921	0.1310	7.5%	4.8%
	Underdrain		1.2367	0.1269		1.1151	0.0214	0.0162				
Total		2.7035		0.2291			0.0383	0.0274	2.4852	0.2291		8.4%

total rainfall (in)	27.74
drainage area (ac)	2.014
overall runoff coeff	0.581

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	543,839	543,839	60,159	465,272	18,408	0	0	266,786	277,592	51.0%	18.6%
	Underdrain		465,272	217,456		248,378	550	11				
Bioretention S	Pond + Media	948,105	948,105	131,779	741,827	74,498	0	0	487,720	461,304	48.6%	30.9%
	Underdrain		741,827	329,564		413,223	939	19				
Total		1,491,943		738,958			1,489	30	754,506	738,896		49.5%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	1.8168	1.8168	0.0330	1.7388	0.0451	0.0000	0.0000	1.2127	0.6206	33.7%	12.3%
	Underdrain		1.7388	0.5878		1.1676	0.0273	0.0108				
Bioretention S	Pond + Media	3.1675	3.1675	0.0786	2.8961	0.1928	0.0000	0.0000	2.1860	1.0060	31.3%	19.9%
	Underdrain		2.8961	0.9276		1.9933	0.0435	0.0189				
Total		4.9843		1.6269			0.0708	0.0297	3.3987	1.6266		32.2%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.9701	0.9701	0.1165	0.7221	0.1315	0.0000	0.0000	0.5680	0.4029	41.5%	15.1%
	Underdrain		0.7221	0.2864		0.4365	0.0008	0.0000				
Bioretention S	Pond + Media	1.6909	1.6909	0.2271	1.1271	0.3368	0.0000	0.0000	1.0404	0.6520	38.5%	24.5%
	Underdrain		1.1271	0.4249		0.7036	0.0014	0.0000				
Total		2.6610		1.0550			0.0023	0.0001	1.6084	1.0549		39.6%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	1.4734	1.4734	0.1175	1.2139	0.1420	0.0000	0.0000	0.8802	0.5961	40.4%	14.7%
	Underdrain		1.2139	0.4787		0.7382	0.0031	0.0002				
Bioretention S	Pond + Media	2.5681	2.5681	0.2403	1.9417	0.3861	0.0000	0.0000	1.5986	0.9745	37.9%	24.1%
	Underdrain		1.9417	0.7343		1.2126	0.0053	0.0004				
Total		4.0415		1.5708			0.0085	0.0006	2.4789	1.5706		38.8%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.5644	0.5644	0.0119	0.5379	0.0146	0.0000	0.0000	0.3699	0.1995	34.9%	12.7%
	Underdrain		0.5379	0.1877		0.3553	0.0075	0.0025				
Bioretention S	Pond + Media	0.9840	0.9840	0.0284	0.8954	0.0602	0.0000	0.0000	0.6691	0.3226	32.4%	20.6%
	Underdrain		0.8954	0.2944		0.6089	0.0121	0.0043				
Total		1.5483		0.5223			0.0196	0.0068	1.0390	0.5222		33.3%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.2237	0.2237	0.0047	0.2133	0.0057	0.0000	0.0000	0.1466	0.0791	34.9%	12.7%
	Underdrain		0.2133	0.0744		0.1409	0.0030	0.0010				
Bioretention S	Pond + Media	0.3902	0.3902	0.0112	0.3552	0.0238	0.0000	0.0000	0.2651	0.1281	32.4%	20.6%
	Underdrain		0.3552	0.1169		0.2413	0.0048	0.0017				
Total		0.6139		0.2073			0.0077	0.0027	0.4117	0.2072		33.3%

Table K-9 2007-2010 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	3.8158	3.8158	0.0149	3.1883	0.6127	0.0000	0.0000	3.3959	0.4087	10.7%	3.9%
	Underdrain		3.1883	0.3938		2.7832	0.0000	0.0112				
Bioretention S	Pond + Media	6.6937	6.6937	0.0212	5.0940	1.5784	0.0000	0.0000	6.1429	0.5345	8.0%	5.1%
	Underdrain		5.0940	0.5133		4.5645	0.0000	0.0162				
Total		10.5095		0.9432			0.0000	0.0274	9.5388	0.9432		9.0%

total rainfall (in)	112.271
drainage area (ac)	2.014
overall runoff coeff	0.558

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2,254,051	2,254,051	264,910	1,930,367	58,776	0	0	1,027,293	1,226,747	54.4%	19.8%
	Underdrain		1,930,367	961,838		968,517	0	11				
Bioretention S	Pond + Media	3,952,892	3,952,892	585,217	3,089,285	278,391	0	0	1,978,371	1,974,501	50.0%	31.8%
	Underdrain		3,089,285	1,389,286		1,699,980	0	19				
Total		6,206,943		3,201,250			0	30	3,005,665	3,201,248		51.6%

ORGN

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	7.7301	7.7301	0.1554	7.4230	0.1517	0.0000	0.0000	4.9907	2.7286	35.3%	12.8%
	Underdrain		7.4230	2.5730		4.8391	0.0000	0.0108				
Bioretention S	Pond + Media	13.5419	13.5419	0.3667	12.4076	0.7676	0.0000	0.0000	9.4639	4.0592	30.0%	19.1%
	Underdrain		12.4076	3.6924		8.6963	0.0000	0.0189				
Total		21.2720		6.7875			0.0000	0.0297	14.4546	6.7877		31.9%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	3.6049	3.6049	0.4162	2.7736	0.4151	0.0000	0.0000	1.9902	1.6148	44.8%	16.3%
	Underdrain		2.7736	1.1985		1.5751	0.0000	0.0000				
Bioretention S	Pond + Media	6.3249	6.3249	0.8439	4.3771	1.1039	0.0000	0.0000	3.7721	2.5528	40.4%	25.7%
	Underdrain		4.3771	1.7089		2.6682	0.0000	0.0000				
Total		9.9298		4.1675			0.0000	0.0001	5.7623	4.1675		42.0%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	6.0237	6.0237	0.4997	5.0626	0.4614	0.0000	0.0000	3.3918	2.6316	43.7%	15.9%
	Underdrain		5.0626	2.1320		2.9304	0.0000	0.0002				
Bioretention S	Pond + Media	10.5365	10.5365	1.0530	8.1302	1.3533	0.0000	0.0000	6.4301	4.1060	39.0%	24.8%
	Underdrain		8.1302	3.0530		5.0768	0.0000	0.0004				
Total		16.5602		6.7376			0.0000	0.0006	9.8220	6.7377		40.7%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2.4288	2.4288	0.0568	2.3228	0.0491	0.0000	0.0000	1.5345	0.8918	36.7%	13.3%
	Underdrain		2.3228	0.8349		1.4854	0.0000	0.0025				
Bioretention S	Pond + Media	4.2539	4.2539	0.1336	3.8777	0.2426	0.0000	0.0000	2.9138	1.3358	31.4%	20.0%
	Underdrain		3.8777	1.2022		2.6712	0.0000	0.0043				
Total		6.6827		2.2275			0.0000	0.0068	4.4483	2.2275		33.3%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	0.9679	0.9679	0.0225	0.9261	0.0193	0.0000	0.0000	0.6119	0.3550	36.7%	13.3%
	Underdrain		0.9261	0.3325		0.5927	0.0000	0.0010				
Bioretention S	Pond + Media	1.7063	1.7063	0.0534	1.5493	0.1036	0.0000	0.0000	1.1725	0.5320	31.2%	19.9%
	Underdrain		1.5493	0.4786		1.0689	0.0000	0.0017				
Total		2.6742		0.8870			0.0000	0.0027	1.7844	0.8871		33.2%

Table K-10 Summary of Flow and Load Removed of Subbasin 420 BMP Performance Evaluation Modeling

FLOW

BMP	Flow removed (ac-ft)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.1175	0.0812	0.1119	0.0981	0.4087	6.4%	34.6%	14.7%	9.8%	10.7%	2.3%	12.6%	5.3%	3.6%	3.9%
Bioretention S	0.1520	0.1078	0.1438	0.1310	0.5345	4.7%	26.3%	10.8%	7.5%	8.0%	3.0%	16.7%	6.9%	4.8%	5.1%
Total	0.2695	0.1889	0.2557	0.2291	0.9432						5.3%	29.3%	12.2%	8.4%	9.0%

BACT

BMP	Load removed (10^6)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	408,773	159,976	380,406	277,592	1,226,747	51.2%	63.5%	57.7%	51.0%	54.4%	18.4%	23.2%	21.0%	18.6%	19.8%
Bioretention S	651,987	247,375	613,836	461,304	1,974,501	46.0%	56.4%	53.4%	48.6%	50.0%	29.4%	35.8%	33.9%	30.9%	31.8%
Total	1,060,760	407,351	994,241	738,896	3,201,248						47.9%	59.0%	55.0%	49.5%	51.6%

ORGN

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.7081	0.4573	0.9426	0.6206	2.7286	26.0%	51.3%	41.0%	33.7%	35.3%	9.4%	18.7%	14.9%	12.3%	12.8%
Bioretention S	1.0320	0.6530	1.3682	1.0060	4.0592	21.5%	42.0%	34.1%	31.3%	30.0%	13.7%	26.7%	21.7%	19.9%	19.1%
Total	1.7401	1.1102	2.3108	1.6266	6.7877						23.1%	45.4%	36.6%	32.2%	31.9%

NH3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.6125	0.1731	0.4263	0.4029	1.6148	39.9%	59.0%	52.9%	41.5%	44.8%	14.4%	21.5%	19.3%	15.1%	16.3%
Bioretention S	0.9546	0.2662	0.6800	0.6520	2.5528	35.1%	52.1%	48.4%	38.5%	40.4%	22.4%	33.1%	30.7%	24.5%	25.7%
Total	1.5671	0.4393	1.1063	1.0549	4.1675						36.8%	54.6%	50.0%	39.6%	42.0%

NO3N

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.9047	0.3420	0.7888	0.5961	2.6316	37.8%	58.0%	50.4%	40.4%	43.7%	13.7%	21.1%	18.4%	14.7%	15.9%
Bioretention S	1.3921	0.5114	1.2280	0.9745	4.1060	33.0%	49.7%	45.0%	37.9%	39.0%	21.1%	31.6%	28.6%	24.1%	24.8%
Total	2.2968	0.8535	2.0168	1.5706	6.7377						34.8%	52.7%	47.0%	38.8%	40.7%

ORGP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.2468	0.1403	0.3051	0.1995	0.8918	28.2%	52.0%	42.3%	34.9%	36.7%	10.2%	19.0%	15.4%	12.7%	13.3%
Bioretention S	0.3638	0.2011	0.4482	0.3226	1.3358	23.6%	42.8%	35.7%	32.4%	31.4%	15.0%	27.2%	22.7%	20.6%	20.0%
Total	0.6107	0.3415	0.7532	0.5222	2.2275						25.3%	46.1%	38.1%	33.3%	33.3%

ORTHOP

BMP	Load removed (lbs)					% removed (based on BMP inflow)					% removed (based on total inflow)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Bioretention W	0.0990	0.0561	0.1209	0.0791	0.3550	28.2%	52.1%	42.4%	34.9%	36.7%	10.1%	19.0%	15.4%	12.7%	13.3%
Bioretention S	0.1461	0.0803	0.1775	0.1281	0.5320	23.2%	42.8%	35.7%	32.4%	31.2%	14.9%	27.2%	22.7%	20.6%	19.9%
Total	0.2451	0.1364	0.2984	0.2072	0.8871						24.9%	46.2%	38.1%	33.3%	33.2%

L. Subbasin 560 BMP Performance Evaluation Modeling

Site Description and Land uses

This is the site used for site-scale HSPF model calibration. Details of this model can be found in Attachment A, “Calibration of Site-Scale HSPF Model”. Instead of the storm event simulation in the calibration, simulation was performed for the 2007 to 2010 period. Note that the model was originally developed for the proof-of-concept project and no design-level detail was involved.

A bioswale layout is placed along the median of Sydney Brooks Drive and City-Base Landing as shown in Exhibit L-1. The pervious and impervious areas are shown in Table L-1. The original USAR subbasin-scale watershed model with simulation period from 2007 to 2010 was modified to use the parameters from the site-scale model calibration and to include the BMP to be modeled for the Subbasin 560 site. The procedure of modifying the model file was similar to that described for the Subbasin 70 site-scale modeling in Attachment B.

Exhibit L-1 Selected Site for Subbasin 560

Table L-1 Land uses of Subbasin 560 BMP Site

Land use	IC%	Pervious Area (ac)	Impervious Area (ac)	Total Area (ac)
Undeveloped Meadow	0	0.1131	0	0.1131
Residential High Density	60	0.0996	0.1493	0.2489
Commercial	58	1.1052	1.5261	2.6313
Transportation	90	0.0497	0.4482	0.4979
TOTAL	60.8	1.3676	2.1236	3.4912

Note: The IC% used in the calibration model are from the proof-of-concept site-scale study and are different from those in the 2017 land use data.

Water Quality Volume Calculations

Using the WQV formula discussed in Section C, the required WQV for the selected BMP site is:
1.5”/12 x 0.6 x 2.1236 ac x 1.2 = 0.191 ac-ft

where the 1.2 is to apply 20% additional WQV to allow for long-term sediment accumulation in the BMP. This 20% contingency factor is required by the River Authority’s LID Manual (SARA, 2019; page B-117). The water quality volume and surface area of the BMP are shown in Table L-2.

Table L-2 Water Quality Volume and Surface Area of Subbasin 560 BMP Site

BMP	WQV (ac-ft)	Surface area (ac)
Bioswale	0.5708	0.4114
Required	0.1910	

Note: Surface area is the area at the water level of the WQV.

Results

As listed in Table L-3, using the model output flows and EC loads, the Geomean and flow-weighted Geomean of EC concentrations were calculated for the BMP inflow and outflow over the 4-year simulation period. The Geomeans listed include values for the inflow and outflow of the bioswale only as well as for the system (i.e., bioswale and bypass). Both the outflow EC Geomeans and flow-weighted Geomeans of the bioswale are substantially lower than the inflow.

For the entire system including the bypass, because most of the inflows to the bioswale infiltrated to the ground, most of the time the outflow concentration was similar to the concentration of the bypass flow concentrations, which were the same as the inflow concentrations. However, similar to the bioswale in Subbasin 70, when there were overflows from the bioswale containing delayed high-concentration water, the outflow Geomean and flow-weighted Geomean are higher than the inflow.

Modeled output annual inflows and outflows from 2007 to 2010 including flows, bacteria and nutrient loads are listed in Tables L-4 to L-7. The flows and loads removed by the bioswale BMP and the corresponding removal percentages are also listed in these tables. Table L-8 shows the same set of information for the 4-year total. The loads removed and removal percentages calculated are summarized in Table L-9 for easier comparison. The Triple Bottom Line Analysis conducted by Autocase includes such considerations and provides a more comprehensive evaluation of the costs and multi benefits of the BMPs.

As noted in the calibration technical memo, the flow into the bioswale was almost entirely infiltrated. The load reduction achieved by the BMP was mostly due to removing the EC load in the infiltrated flow. When excluding the bypass flows, the removal percentages are close to 100%.

When the bypass flows are included, however, the removal percentages drop to low 20s since the inflow to the bioswale is 22.9% of the total flow. In 2008, a dry year, the flows were small enough that all flows were infiltrated. As a result, the removal percentages excluding and including the bypass flow are 100% and 22.9%, respectively, for 2008.

Note that the "removed" EC might stay and continue to reproduce in the bottom sediment/soil of a bioswale. If so, these EC might be resuspended by future storm events and reappear in the water column resulting in higher concentrations in the outflow than inflow. This "BMP becoming an incubator of pollutant loads" has been reported in publications/presentations such as StormCon. A monitoring program is recommended to document long-term removal for bioswale located on sandy soil where infiltration is high and 100% removal through infiltration is possible.

Table L-3 EC Concentrations of Subbasin 560 BMP Layouts Over 2007-2010

BMP	Inflow		Outflow	
	Geomean (#/dL)	Flow-weighted geomean (#/dL)	Geomean (#/dL)	Flow-weighted geomean (#/dL)
Bioswale (exclude bypass)	49,415	9,222	4,309	4,406
System (include bypass)	49,417	9,222	50,008	10,708

Table L-4 2007 Flows and Loads of Subbasin 560 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Total flow (ac-ft)	Bypass flow (ac-ft)	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	27.2189	20.9856	6.2333	6.2333	0.0199	5.3633	0.8502	0.0000	0.0000	1.9494	4.2839	68.7%	15.7%
	Underdrain				5.3633	0.0515	4.2125	1.0992	0.0000	0.0000				

total rainfall (in)	48.295
drainage area (ac)	15.245
overall runoff coeff	0.444

BACT

BMP	Components	Total load (10^6)	Bypass load (10^6)	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	6,478,861	4,995,153	1,483,709	1,483,709	88,315	1,342,896	52,499	0	0	137,870	1,345,839	90.7%	20.8%
	Underdrain				1,342,896	164,187	1,093,337	85,371	0	0				

ORGN

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	40.5210	31.2413	9.2797	9.2797	0.0843	8.9917	0.2037	0.0000	0.0000	0.7991	8.4806	91.4%	20.9%
	Underdrain				8.9917	0.2010	8.1953	0.5954	0.0000	0.0000				

NH3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	22.6422	17.4569	5.1852	5.1852	0.3892	4.1577	0.6384	0.0000	0.0000	1.1192	4.0660	78.4%	18.0%
	Underdrain				4.1577	0.5041	3.1728	0.4808	0.0000	0.0000				

NO3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	34.7066	26.7584	7.9481	7.9481	0.3883	6.9441	0.6157	0.0000	0.0000	1.3225	6.6256	83.4%	19.1%
	Underdrain				6.9441	0.6110	5.6263	0.7068	0.0000	0.0000				

ORGP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	12.9814	10.0086	2.9729	2.9729	0.0315	2.8812	0.0602	0.0000	0.0000	0.2502	2.7226	91.6%	21.0%
	Underdrain				2.8812	0.0735	2.6177	0.1900	0.0000	0.0000				

ORTHOP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	5.4666	4.2147	1.2519	1.2519	0.0146	1.1854	0.0520	0.0000	0.0000	0.1366	1.1153	89.1%	20.4%
	Underdrain				1.1854	0.0310	1.0698	0.0846	0.0000	0.0000				

Table L-5 2008 Flows and Loads of Subbasin 560 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Total flow (ac-ft)	Bypass flow (ac-ft)	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	3.3608	2.5911	0.7696	0.7696	0.0006	0.7691	0.0000	0.0000	0.0000	0.0000	0.7696	100.0%	22.9%
	Underdrain				0.7691	0.0103	0.7588	0.0000	0.0000	0.0000				

total rainfall (in)	10.971
drainage area (ac)	15.245
overall runoff coeff	0.241

BACT

BMP	Components	Total load (10^6)	Bypass load (10^6)	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	1,928,021	1,486,490	441,531	441,531	1,095	440,436	0	0	0	0	441,531	100.0%	22.9%
	Underdrain				440,436	24,268	416,168	0	0	0				

ORGN

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	12.7636	9.8406	2.9230	2.9230	0.0003	2.9227	0.0000	0.0000	0.0000	0.0000	2.9230	100.0%	22.9%
	Underdrain				2.9227	0.0236	2.8991	0.0000	0.0000	0.0000				

NH3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	4.0310	3.1078	0.9231	0.9231	0.0043	0.9189	0.0000	0.0000	0.0000	0.0000	0.9231	100.0%	22.9%
	Underdrain				0.9189	0.0403	0.8786	0.0000	0.0000	0.0000				

NO3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	8.2513	6.3617	1.8896	1.8896	0.0034	1.8862	0.0000	0.0000	0.0000	0.0000	1.8896	100.0%	22.9%
	Underdrain				1.8862	0.0621	1.8242	0.0000	0.0000	0.0000				

ORGP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	3.8608	2.9766	0.8841	0.8841	0.0001	0.8840	0.0000	0.0000	0.0000	0.0000	0.8841	100.0%	22.9%
	Underdrain				0.8840	0.0086	0.8755	0.0000	0.0000	0.0000				

ORTHOP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	1.5393	1.1868	0.3525	0.3525	0.0001	0.3525	0.0000	0.0000	0.0000	0.0000	0.3525	100.0%	22.9%
	Underdrain				0.3525	0.0034	0.3491	0.0000	0.0000	0.0000				

Table L-6 2009 Flows and Loads of Subbasin 560 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Total flow (ac-ft)	Bypass flow (ac-ft)	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	10.9294	8.4265	2.5029	2.5029	0.0077	2.4952	0.0000	0.0000	0.0000	0.2040	2.2989	91.8%	21.0%
	Underdrain				2.4952	0.0249	2.2662	0.2040	0.0000	0.0000				

total rainfall (in)	25.265
drainage area (ac)	15.245
overall runoff coeff	0.341

BACT

BMP	Components	Total load (10^6)	Bypass load (10^6)	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	5,047,997	3,891,969	1,156,028	1,156,028	31,808	1,124,223	0	0	0	27,610	1,128,418	97.6%	22.4%
	Underdrain				1,124,223	113,572	983,040	27,610	0	0				

ORGN

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	32.9032	25.3681	7.5351	7.5351	0.0291	7.5060	0.0000	0.0000	0.0000	0.1716	7.3635	97.7%	22.4%
	Underdrain				7.5060	0.1287	7.2057	0.1716	0.0000	0.0000				

NH3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	11.2515	8.6748	2.5767	2.5767	0.0724	2.5043	0.0000	0.0000	0.0000	0.0986	2.4781	96.2%	22.0%
	Underdrain				2.5043	0.2354	2.1703	0.0986	0.0000	0.0000				

NO3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	21.9112	16.8934	5.0179	5.0179	0.0934	4.9245	0.0000	0.0000	0.0000	0.1634	4.8544	96.7%	22.2%
	Underdrain				4.9245	0.3320	4.4290	0.1634	0.0000	0.0000				

ORGP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	10.3102	7.9490	2.3611	2.3611	0.0108	2.3503	0.0000	0.0000	0.0000	0.0568	2.3043	97.6%	22.3%
	Underdrain				2.3503	0.0467	2.2467	0.0568	0.0000	0.0000				

ORTHOP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	4.0838	3.1486	0.9352	0.9352	0.0043	0.9310	0.0000	0.0000	0.0000	0.0222	0.9130	97.6%	22.4%
	Underdrain				0.9310	0.0185	0.8903	0.0222	0.0000	0.0000				

Table L-7 2010 Flows and Loads of Subbasin 560 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Total flow (ac-ft)	Bypass flow (ac-ft)	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	14.1021	10.8726	3.2295	3.2295	0.0111	3.1504	0.0681	0.0000	0.0000	0.8292	2.4003	74.3%	17.0%
	Underdrain				3.1504	0.0225	2.3667	0.7611	0.0000	0.0000				

total rainfall (in)	27.74
drainage area (ac)	15.245
overall runoff coeff	0.400

BACT

BMP	Components	Total load (10^6)	Bypass load (10^6)	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	4,166,786	3,212,559	954,227	954,227	24,867	927,651	1,708	0	0	53,339	900,888	94.4%	21.6%
	Underdrain				927,651	93,661	782,358	51,632	0	0				

ORGN

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	26.0116	20.0547	5.9569	5.9569	0.0162	5.9370	0.0037	0.0000	0.0000	0.2956	5.6613	95.0%	21.8%
	Underdrain				5.9370	0.1014	5.5436	0.2919	0.0000	0.0000				

NH3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	13.4220	10.3482	3.0738	3.0738	0.1872	2.8427	0.0439	0.0000	0.0000	0.4045	2.6693	86.8%	19.9%
	Underdrain				2.8427	0.3173	2.1647	0.3606	0.0000	0.0000				

NO3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	20.7044	15.9629	4.7415	4.7415	0.1555	4.5432	0.0427	0.0000	0.0000	0.5032	4.2383	89.4%	20.5%
	Underdrain				4.5432	0.3352	3.7475	0.4605	0.0000	0.0000				

ORGP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	8.0806	6.2301	1.8505	1.8505	0.0061	1.8430	0.0014	0.0000	0.0000	0.0932	1.7573	95.0%	21.7%
	Underdrain				1.8430	0.0366	1.7146	0.0918	0.0000	0.0000				

ORTHOP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal	
													Exc. bypass	Inc. bypass
Bioswale	Swale + Media	3.2070	2.4726	0.7344	0.7344	0.0024	0.7315	0.0006	0.0000	0.0000	0.0368	0.6976	95.0%	21.8%
	Underdrain				0.7315	0.0145	0.6807	0.0363	0.0000	0.0000				

Table L-8 2007-2010 Flows and Loads of Subbasin 560 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Total flow (ac-ft)	Bypass flow (ac-ft)	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	55.6112	42.8758	12.7354	12.7354	0.0392	11.7780	0.9183	0.0000	0.0000	2.9827	9.7528	76.6%	17.5%
	Underdrain				11.7780	0.1092	9.6043	2.0644	0.0000	0.0000				

total rainfall (in)	112.271
drainage area (ac)	15.245
overall runoff coeff	0.390

BACT

BMP	Components	Total load (10^6)	Bypass load (10^6)	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	17,621,666	13,586,170	4,035,496	4,035,496	146,085	3,835,206	54,207	0	0	218,819	3,816,677	94.6%	21.7%
	Underdrain				3,835,206	395,689	3,274,903	164,612	0	0				

ORGN

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	112.1994	86.5047	25.6947	25.6947	0.1299	25.3574	0.2074	0.0000	0.0000	1.2663	24.4284	95.1%	21.8%
	Underdrain				25.3574	0.4547	23.8437	1.0589	0.0000	0.0000				

NH3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	51.3466	39.5878	11.7588	11.7588	0.6531	10.4235	0.6822	0.0000	0.0000	1.6222	10.1366	86.2%	19.7%
	Underdrain				10.4235	1.0971	8.3865	0.9400	0.0000	0.0000				

NO3N

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	85.5734	65.9764	19.5971	19.5971	0.6406	18.2980	0.6584	0.0000	0.0000	1.9891	17.6080	89.9%	20.6%
	Underdrain				18.2980	1.3404	15.6270	1.3307	0.0000	0.0000				

ORGP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	35.2330	27.1643	8.0687	8.0687	0.0485	7.9585	0.0616	0.0000	0.0000	0.4003	7.6684	95.0%	21.8%
	Underdrain				7.9585	0.1655	7.4544	0.3386	0.0000	0.0000				

ORTHOP

BMP	Components	Total load (lbs)	Bypass load (lbs)	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	Removal Exc. bypass	Removal Inc. bypass
Bioswale	Swale + Media	14.2967	11.0226	3.2741	3.2741	0.0213	3.2003	0.0525	0.0000	0.0000	0.1956	3.0785	94.0%	21.5%
	Underdrain				3.2003	0.0673	2.9899	0.1431	0.0000	0.0000				

Table L-9 Summary of Flow and Load Removed of Subbasin 560 BMP Performance Evaluation Modeling

Constituent	Flow removed (ac-ft)					% removed (exc. bypass)					% removed (inc. bypass)				
	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year	2007	2008	2009	2010	4-year
Flow	4.2839	0.7696	2.2989	2.4003	9.7528	68.7%	100.0%	91.8%	74.3%	76.6%	15.7%	22.9%	21.0%	17.0%	17.5%
BACT	1,345,839	441,531	1,128,418	900,888	3,816,677	90.7%	100.0%	97.6%	94.4%	94.6%	20.8%	22.9%	22.4%	21.6%	21.7%
ORGN	8.4806	2.9230	7.3635	5.6613	24.4284	91.4%	100.0%	97.7%	95.0%	95.1%	20.9%	22.9%	22.4%	21.8%	21.8%
NH3N	4.0660	0.9231	2.4781	2.6693	10.1366	78.4%	100.0%	96.2%	86.8%	86.2%	18.0%	22.9%	22.0%	19.9%	19.7%
NO3N	6.6256	1.8896	4.8544	4.2383	17.6080	83.4%	100.0%	96.7%	89.4%	89.9%	19.1%	22.9%	22.2%	20.5%	20.6%
ORGP	2.7226	0.8841	2.3043	1.7573	7.6684	91.6%	100.0%	97.6%	95.0%	95.0%	21.0%	22.9%	22.3%	21.7%	21.8%
ORTHOP	1.1153	0.3525	0.9130	0.6976	3.0785	89.1%	100.0%	97.6%	95.0%	94.0%	20.4%	22.9%	22.4%	21.8%	21.5%

Subtask 5.1 - Triple Bottom Line (TBL) and Sustainable Return of Investment (SROI) Evaluation Report

The evaluation report on TBL benefits (social, environmental, economic) and SROI findings for the eight proposed GSI implementation sites. Report begins on next page.

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

EXECUTIVE SUMMARY

REPORT AUTHOR
AUTOCASE ECONOMIC ADVISORY
(BY IMPACT INFRASTRUCTURE, INC.)

PREPARED FOR
SAN ANTONIO RIVER AUTHORITY
(SARA)

JUNE 2021

Autocase
Economic Advisory

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PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

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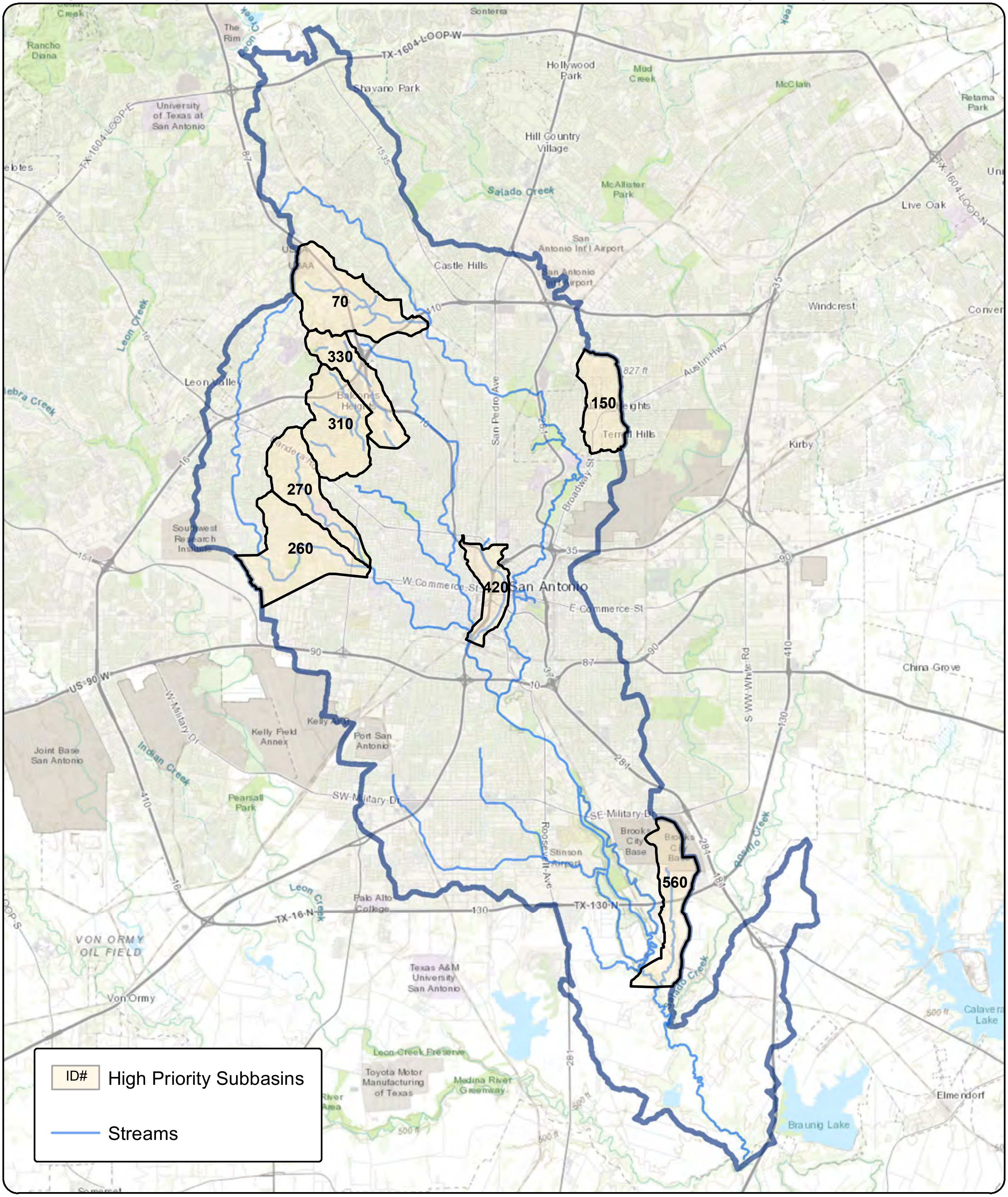
EPA United States Environmental Protection Agency

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

High Priority Subbasins within the Upper San Antonio River (USAR) Watershed



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Produced by: eagarcia Date: 8/30/2019

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EXECUTIVE SUMMARY

The San Antonio River Authority (SARA) received US Environmental Protection Agency (EPA) funding through the Texas Commission on Environmental Quality (TCEQ) to create a Green Stormwater Infrastructure (GSI) Master Plan for portions of the Upper San Antonio River Watershed. During the master planning process, eight traditionally constructed sites on public lands or rights of way were identified and modeled for potential GSI Best Management Practices (BMP) implementation. The evaluation was constructed with a multidisciplinary team of engineers, landscape ecologists, planners, and economists.

An enhanced Cost Benefit Analysis (CBA) approach, also referred to as Triple Bottom Line-Cost Benefit Analysis (TBL-CBA), was then used to value the impacts associated with each site. TBL-CBA is an evidenced-based economic method that combines CBA and Life Cycle Cost Analysis (LCCA) across the Triple Bottom Line (TBL) to weigh the costs and benefits incurred to project stakeholders. It expands the traditional financial analysis (capital and operations and maintenance costs) to account for social and environmental performance as well. It aims to quantify, in monetary terms, as many of the costs and benefits of the project as possible, and converts them all into a present day dollar value representing the Net Present Value (NPV) of the project. The Triple Bottom Line-Net Present Value (TBL-NPV) of the sites is used to compare relative benefits and costs that accrue over their lifetime.

This study investigates the impacts of BMP installations over eight project sites on approximately two and a half acres (combined). The model used an expected construction duration of one year (starting in August 2022), with an operations duration of 50 years as the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. RCP 4.5 is a mild climate scenario where global action on climate change means that emissions peak around 2040, then decline. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars (2020 USD) in order to provide the TBL-NPV. Net present value is a metric used to measure all future cash flows of a project and discount them back to current dollars to allow for comparing different project sites designs on an equal footing.

Table 1. Amount of Pollutant Loadings Removed from Each Individual Project Site (1 - 8) | Over 50 Years

Pollutant	Units	Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
E. Coli Bacteria	#10^6 org	**158,483,250**	**123,456,900**	**261,232,825**	**18,211,850**	**34,769,700**	**37,401,150**	**40,015,600**	**47,708,450**
Total Suspended Solids*	tons	**744**	**39**	**107**	**11**	**12**	**26**	**10**	**100**
Total Nitrogen	lbs	**313**	**961**	**2,517**	**209**	**228**	**295**	**221**	**652**
Total Phosphorus	lbs	**199**	**230**	**574**	**37**	**43**	**55**	**39**	**134**

**Total Suspended Solids pollutant loadings were estimated by Autocase.*

Table 2. Amount of Pollutant Loadings Removed from All Project Sites | Over 50 Years

Pollutant	Units	All Sites
E. Coli Bacteria	#10^6 org	**721,279,725**
Total Suspended Solids*	tons	**1,047**
Total Nitrogen	lbs	**5,396**
Total Phosphorus	lbs	**1,311**

**Total Suspended Solids pollutant loadings were estimated by Autocase.*

The SARA GSI project team developed design scenarios for the proposed BMPs, while Lockwood, Andrews & Newnam (LAN) modeled land cover and water quality in both the base and design case scenarios. Autocase used the outcomes of their work as inputs for the TBL-CBA (Tables 1 & 2). By leveraging this data, as well as best in class peer reviewed literature and government reports, Autocase was able to analyze and compare the TBL benefits between the base case and design scenarios. A summary of these outcomes are shown in Table 3 below, all relative to the existing conditions at the site locations or 'base case' that assumes a managed turf land cover. Shifting away from managed landscape practices allows for co-benefits to accrue to the environment in the forms of improved water quality in the San Antonio River, reduced trash in local waters, along with greater vegetative sequestration, and providing a more conducive habitat for pollinators. These environmental benefits are denoted by the water quality - pollutant loading reduction, trash, (carbon and air pollution) sequestration, and pollination line item results presented in Table 3. This shift towards GSI BMPs also allows for co-benefits to be realized to the society/community in the form of reduced flood risk, eco-literacy education opportunities for local schools, urban heat island reductions, as well as increases in both site recreation and in the inducement of water recreation via improved water quality along the San Antonio River. These social benefits are denoted by the flood risk, education, urban heat island, open space - recreation, and water quality - induced recreation line item results presented in Table 3.

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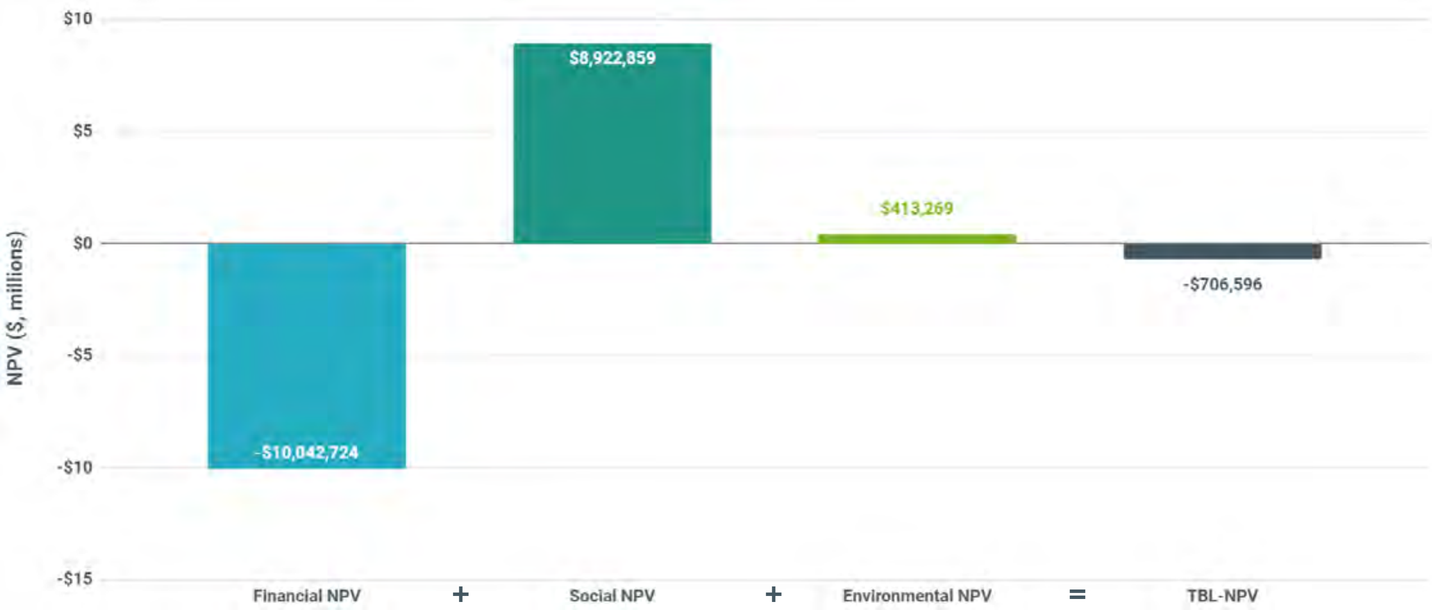
Table 3. Results Summary of All Sites (1 - 8) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
Financial	Capital Costs	-$318,400	-$263,700	-$754,800	-$132,700	-$155,000	-$263,800	-$181,900	-$2,481,000
	Operations & Maintenance	-$450,800	-$543,600	-$1,498,000	-$161,900	-$194,300	-$185,400	-$240,600	-$811,100
	Replacement Costs	-$223,379	-$190,590	-$530,795	-$57,342	-$68,835	-$68,624	-$89,051	-$284,379
	Residual Value	$21,100	$12,700	$35,500	$3,830	$4,600	$4,590	$5,950	$19,000
Social	Flood Risk	$850	$400	$1,156	$72	$221	$93	$221	$647
	Education	$30,915	$0	$30,915	$30,915	$30,915	$0	$0	$0
	Urban Heat Island	$6,700	$3,080	$8,610	$930	$1,120	$1,110	$1,440	$4,620
	Open Space - Recreation	$7,410	$3,250	$1,190	$190	$1,200	$0	$0	$0
	Water Quality - Induced Recreation	$2,126,544	$1,668,031	$2,731,634	$295,244	$354,365	$353,296	$458,359	$767,218
Environmental	Air Pollution from Sequestration	$880	$400	$1,130	$120	$150	$150	$190	$600
	Carbon Emissions from Sequestration	$71,100	$32,700	$91,300	$9,860	$11,800	$11,800	$15,300	$49,000
	Trash	$17,209	$7,846	$22,017	$2,278	$2,784	$2,784	$3,797	$11,895
	Water Quality - Pollutant Loading Reduction	$4,298	$4,412	$11,507	$934	$1,027	$1,363	$982	$3,194
	Pollination	$4,480	$2,062	$5,754	$622	$747	$744	$966	$3,087
	Financial NPV	-$971,479	-$985,190	-$2,748,095	-$348,112	-$413,535	-$513,234	-$505,601	-$3,557,479
	Social NPV	$2,172,419	$1,674,761	$2,773,505	$327,351	$387,821	$354,499	$460,020	$772,485
	Environmental NPV	$97,967	$47,420	$131,708	$13,814	$16,508	$16,841	$21,235	$67,776
	Triple Bottom Line-Net Present Value (TBL-NPV)	$1,298,907	$736,991	$157,118	-$6,947	-$9,206	-$141,895	-$24,346	-$2,717,218

Most project sites are expected to drive negative TBL-NPV impacts, while some return positive results. The largest negative driver of the TBL-NPV results stems from the financial impacts, where higher upfront capital costs and operations & maintenance (O&M) costs have severe implications on the triple bottom line results, as shown for Site 6 and 8 (Table 3) returning a negative financial NPV of approximately $0.51 million and $3.56 million, respectively. Differences in the upfront capital costing estimates are due to the project location and whether it is between traffic lanes, requiring additional concrete reinforcement (lateral struts), and higher costs of construction due to other localized site provisions.

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For All Project Sites (1 - 8) | Net Present Value Over 50 Years Discounted at 3%

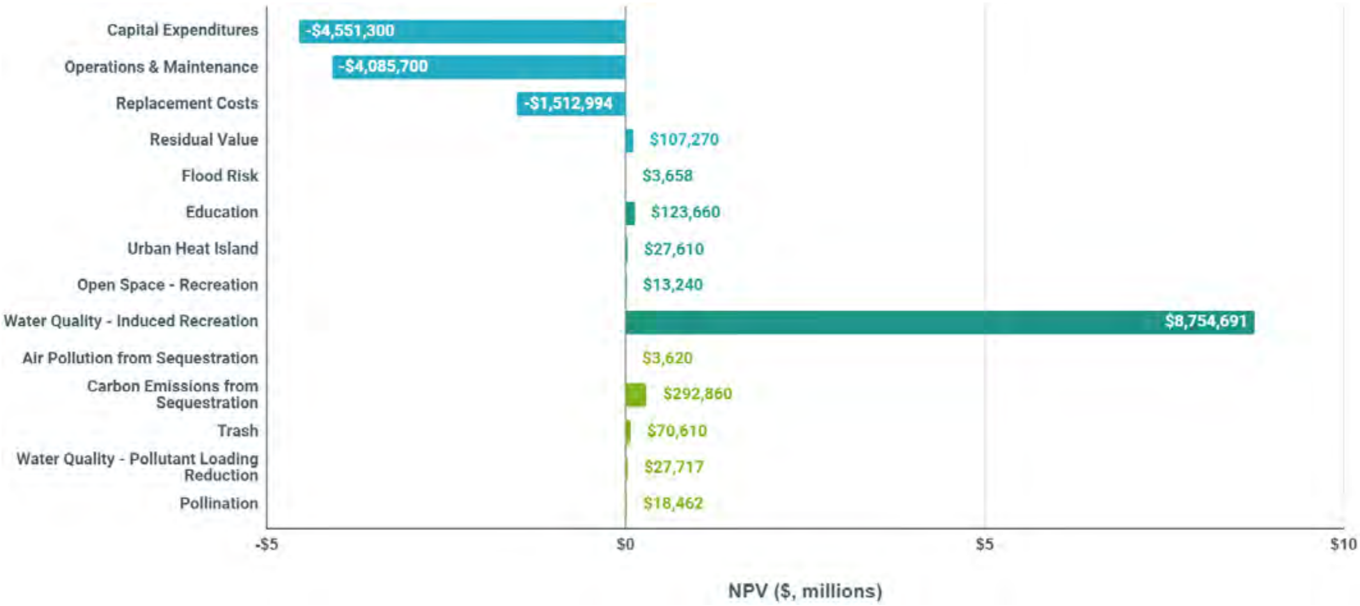


The installation of GSI BMPs is expected to improve local water quality by reducing the pollutant loadings present in stormwater runoff. Implementing GSI offers the opportunity for greater retention of rainfall from the surface areas that drain into project sites. Such BMP installations prevent trash from entering local waterways by more effectively trapping trash compared to managed turf land covers and represents a benefit to the community. This improvement in local water quality is also expected to induce recreation along the San Antonio River, which is the most significant driver of positive TBL-NPV results. This can be clearly seen for Sites 1 and 3 (Table 3), where trash and recreation values are in the top 5 largest drivers of growth; valued at $17,209 and approximately $2.13 million, respectively, for Site 1 and $22,017 and approximately $2.73 million, respectively, for Site 3.

The combined financial NPV of the project sites returns approximately $10 million worth of costs incurred for all of the BMP site installations (Figure 1). This value takes into account the full life cycle costs of the landcover features assumed in both the base and design cases, and is differenced against any operations and maintenance costs estimated for regularly managing turf in the base case.

The social NPV is the largest impact driver in the design case scenario, with GSI BMP designs providing over $8.92 million more in social benefits when compared to conditions in the base case (Figure 1). The GSI Master Plan design case scenario drives value to the local community in terms of the aforementioned induced recreation along the San Antonio River, eco-literacy education opportunities for local schools, increased recreation on or around the GSI BMPs, and reduced urban heat island and flood risk impacts.

Figure 2. Comparison of the Expected NPV of each Category of Results For All Project Sites (1 - 8) | Net Present Value Over 50 Years Discounted at 3%



The design case with GSI BMP implementations also produces a positive environmental NPV that is approximately $0.41 million more than that under the existing managed turf conditions in the base case (Figure 1). These improvements stem from the improved water quality (via reduced pollutant loads), reduced trash in waterways, greater sequestration of greenhouse gases, and other air pollutants from higher vegetative growth, along with benefits accrued to a switch in landscaping practices allowing for greater pollination potential.

When viewed across an aggregated lens of all three TBL categories (financial, social, and environmental impacts) the GSI Master Plan results in a negative TBL-NPV of $0.71 million across all eight project sites identified in the TBL-CBA (Figure 1). When analyzed categorically, the three highest generators of benefits (in order) are through the increased inducement of recreation via water quality improvements, vegetative sequestration of carbon, and eco-literacy opportunities for local schools (Figure 2). The highest generators of costs are from the LCCA related line items incurred to the GSI BMPs' installations: capital expenditures, operations & maintenance, and replacement costs (Figure 2).

These results show that, on a per site basis, some are able to generate positive results, while others do not. Despite the financial expenditures incurred upfront, when viewed holistically across a TBL framework, the investments generate a suite of co-benefits to social and environmental stakeholders that are able to offset much of the lifecycle costs accrued for installing BMPs. For more detailed information on the methodologies and granular inputs used for this report, please visit this link.

TRIPLE BOTTOM LINE-
COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY
GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 1 (SUBBASIN 70) -

REPORT OVERVIEW

REPORT AUTHOR
AUTOCASE ECONOMIC ADVISORY
(BY IMPACT INFRASTRUCTURE, INC.)

PREPARED FOR
SAN ANTONIO RIVER AUTHORITY
(SARA)

MAY 2021

Autocase
Economic Advisory

Table 1. Results for Site 1 (Subbasin 70) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$318,400
	Operations & Maintenance	-$450,800
	Replacement Costs	-$223,379
	Residual Value	$21,100
Social	Flood Risk	$850
	Education	$30,915
	Urban Heat Island	$6,700
	Open Space - Recreation	$7,410
	Water Quality - Induced Recreation	$2,126,544
Environmental	Air Pollution from Sequestration	$880
	Carbon Emissions from Sequestration	$71,100
	Trash	$43,276
	Water Quality - Pollutant Loading Reduction	$4,298
	Pollination	$4,480

Financial NPV	-$971,479
Social NPV	$2,172,419
Environmental NPV	$124,034
Triple Bottom Line-Net Present Value (TBL-NPV)	$1,324,974

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

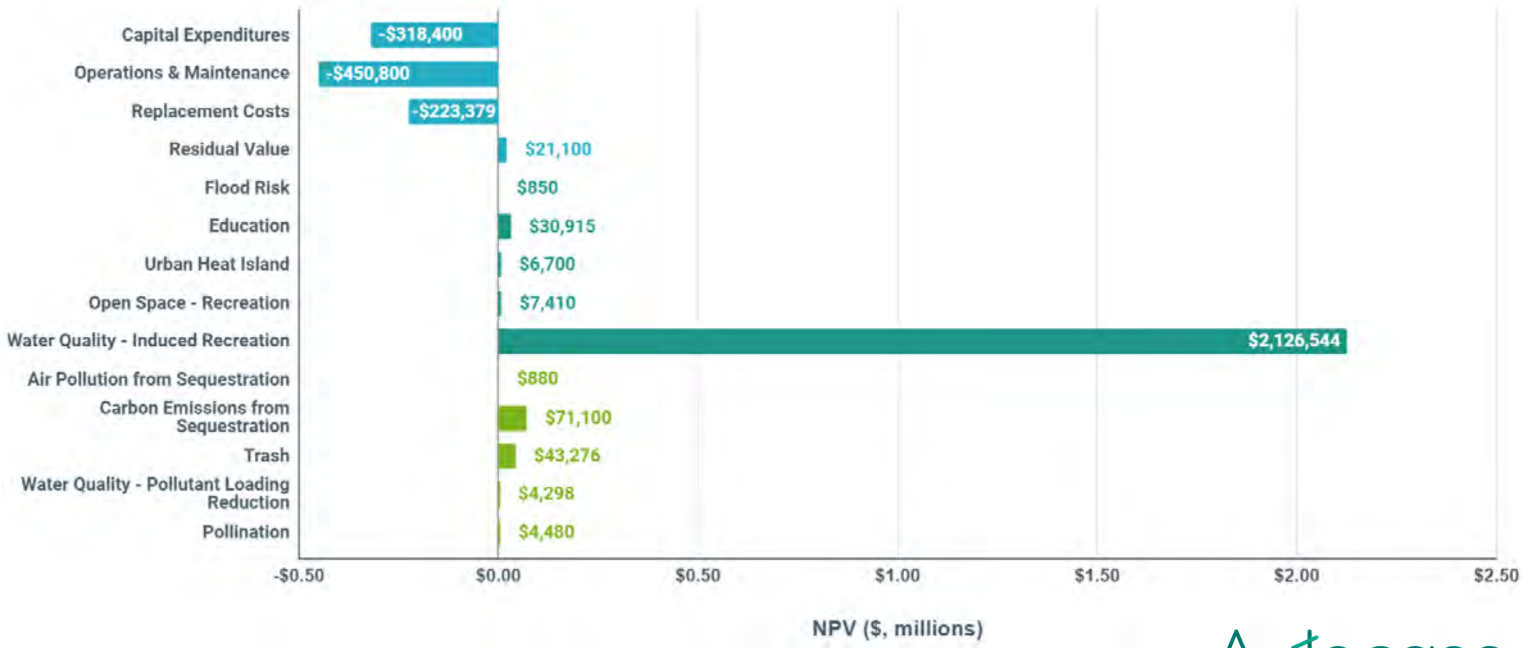
Autocase Economic Advisory

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 1 (Subbasin 70) | Net Present Value Over 50 Years Discounted at 3%

The implementation of the BMPs is expected to drive a positive TBL-NPV when accounting for the financial, social and environmental impacts for Site 1 (Subbasin 70). The total TBL-NPV is $1,324,974 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The social NPV is the biggest driver of the positive results, namely through induced recreation via improved water quality estimated at $2,172,419 (Figure 2). The environmental NPV is the next largest generator of benefits for Site 1 (Subbasin 70) at $124,034, with the majority of the impact category stemming from vegetation sequestration (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 1 (Subbasin 70) | Net Present Value Over 50 Years Discounted at 3%



Autocase Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 2 (SUBBASIN 150) -

REPORT OVERVIEW

REPORT AUTHOR
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(BY IMPACT INFRASTRUCTURE, INC.)

PREPARED FOR
SAN ANTONIO RIVER AUTHORITY
(SARA)

JUNE 2021

Autocase
Economic Advisory

Table 1. Results for Site 2 (Subbasin 150) | Net Present Value Over 50 Years Discounted at 3%

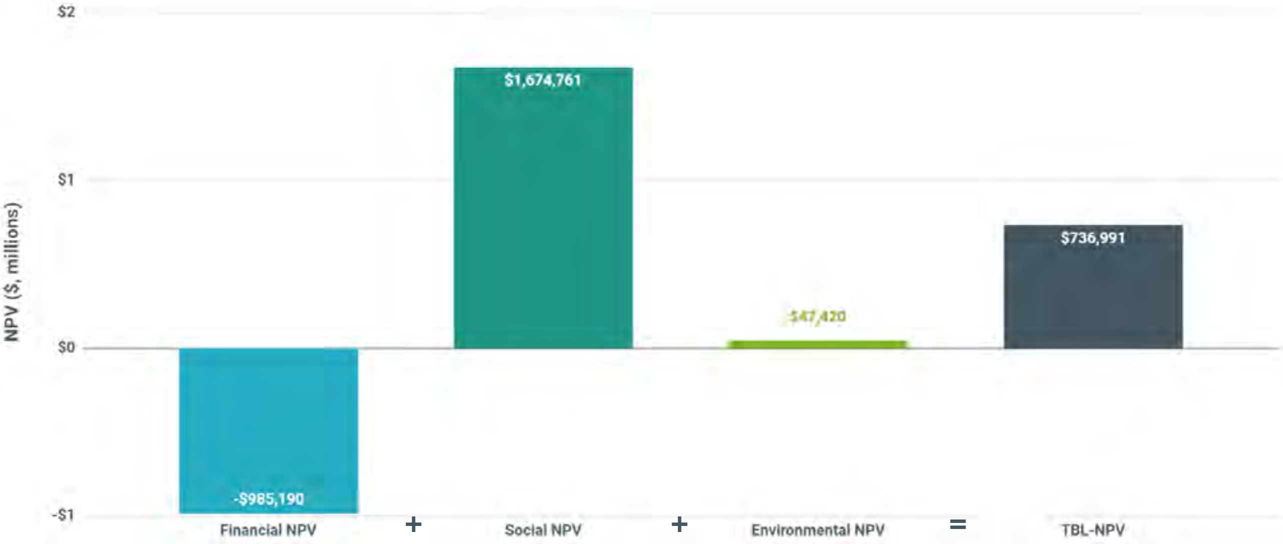
	Impact	Lifetime NPV
Financial	Capital Costs	-$263,700
	Operations & Maintenance	-$543,600
	Replacement Costs	-$190,590
	Residual Value	$12,700
Social	Flood Risk	$400
	Education	$0
	Urban Heat Island	$3,080
	Open Space - Recreation	$3,250
	Water Quality - Induced Recreation	$1,668,031
Environmental	Air Pollution from Sequestration	$400
	Carbon Emissions from Sequestration	$32,700
	Trash	$7,846
	Water Quality - Pollutant Loading Reduction	$4,412
	Pollination	$2,062

Financial NPV	-$985,190
Social NPV	$1,674,761
Environmental NPV	$47,420
Triple Bottom Line-Net Present Value (TBL-NPV)	$736,991

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

Autocase Economic Advisory

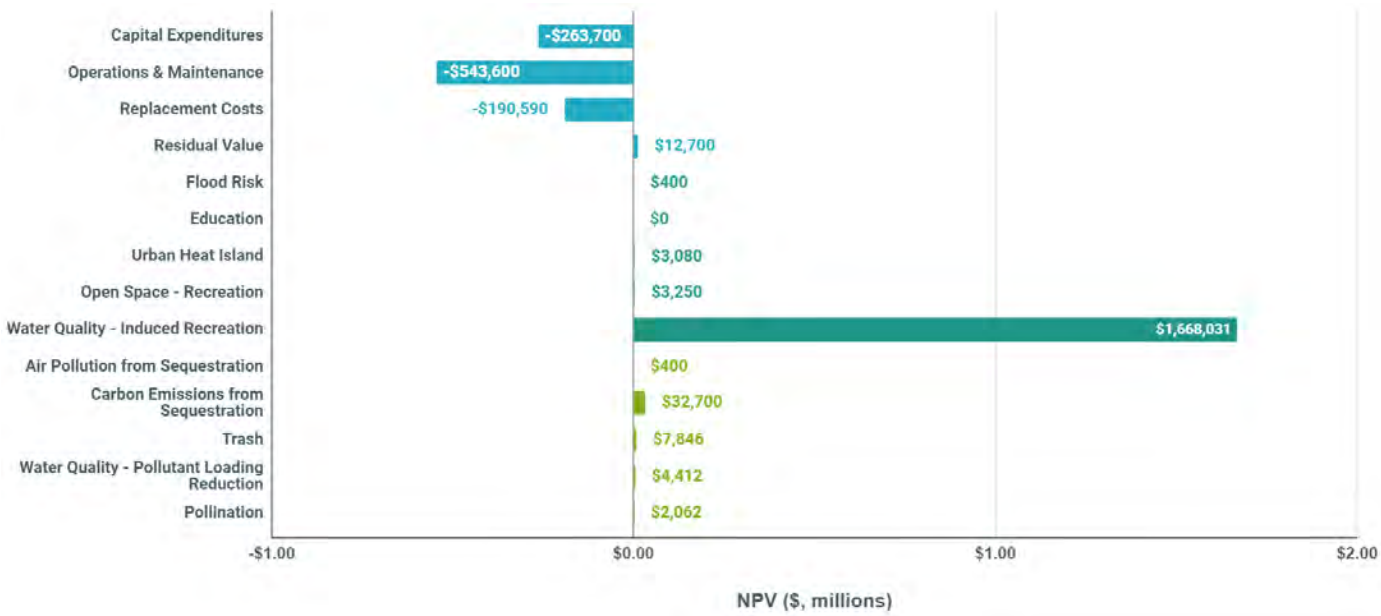
Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 2 (Subbasin 150) | Net Present Value Over 50 Years Discounted at 3%



The implementation of the BMPs is expected to drive a positive TBL-NPV when accounting for the financial, social and environmental impacts for Site 2 (Subbasin 150). The total TBL-NPV is $736,991 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The social NPV is the biggest driver of the positive results, namely through induced recreation via improved water quality estimated at $1,674,761 (Figure 2). The environmental NPV is the next largest generator of benefits for Site 2 (Subbasin 150) at $47,420, with the majority of the impact category stemming from vegetation sequestration (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 2 (Subbasin 150) | Net Present Value Over 50 Years Discounted at 3%



Autocase Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 3 (SUBBASIN 260) -

REPORT OVERVIEW

REPORT AUTHOR
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PREPARED FOR
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(SARA)

MAY 2021

Autocase
Economic Advisory

Table 1. Results for Site 3 (Subbasin 260) | Net Present Value Over 50 Years Discounted at 3%

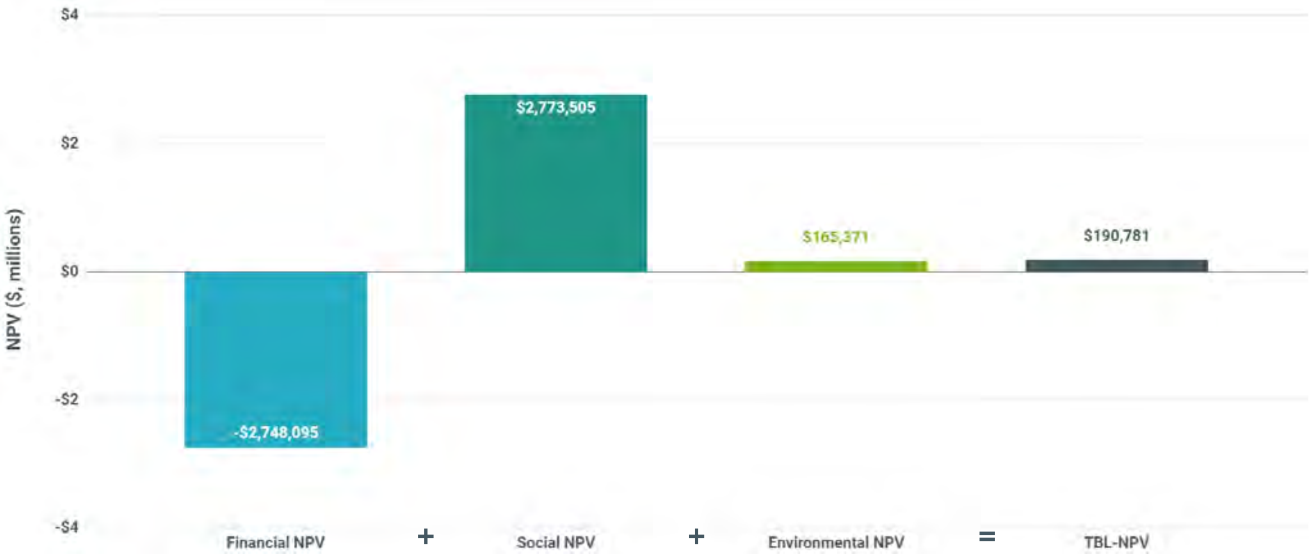
	Impact	Lifetime NPV
Financial	Capital Costs	-$754,800
	Operations & Maintenance	-$1,498,000
	Replacement Costs	-$530,795
	Residual Value	$35,500
Social	Flood Risk	$1,156
	Education	$30,915
	Urban Heat Island	$8,610
	Open Space - Recreation	$1,190
	Water Quality - Induced Recreation	$2,731,634
Environmental	Air Pollution from Sequestration	$1,130
	Carbon Emissions from Sequestration	$91,300
	Trash	$55,676
	Water Quality - Pollutant Loading Reduction	$11,511
	Pollination	$5,754

Financial NPV	-$2,748,095
Social NPV	$2,773,505
Environmental NPV	$165,371
Triple Bottom Line-Net Present Value (TBL-NPV)	$190,781

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

Autocase Economic Advisory

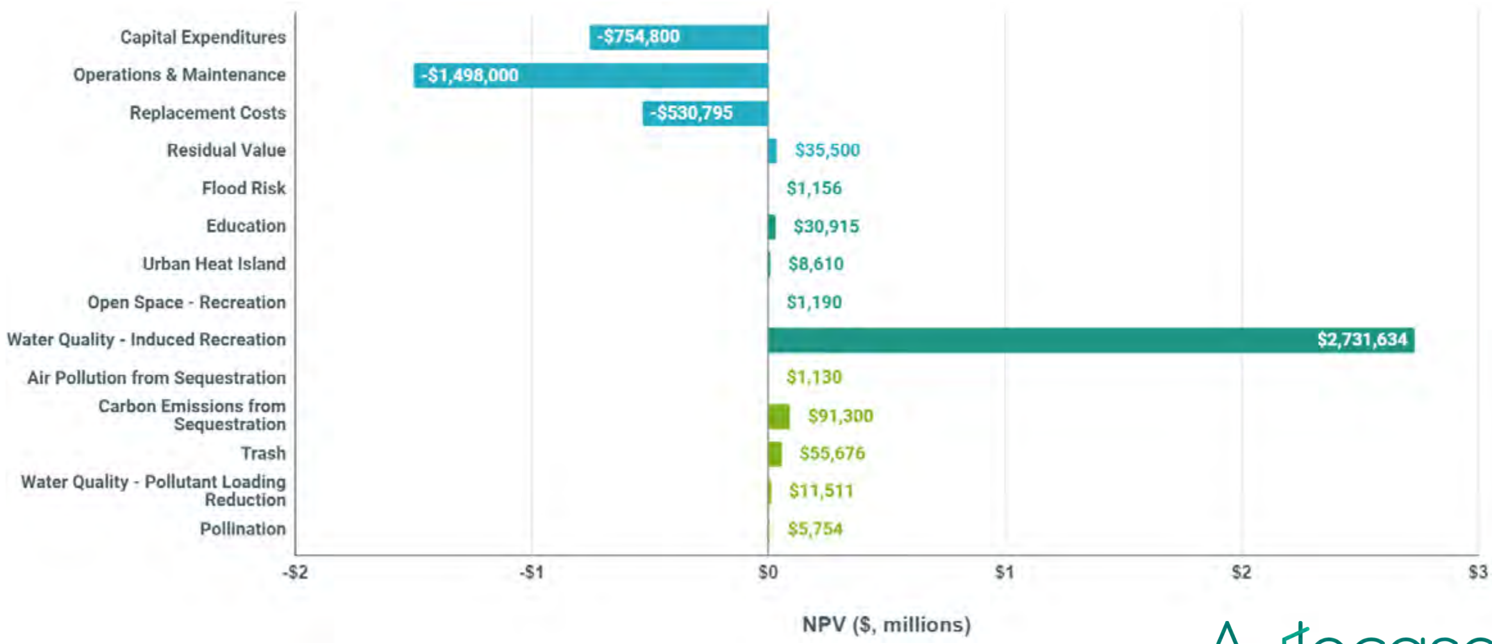
Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 3 (Subbasin 260) | Net Present Value Over 50 Years Discounted at 3%



The implementation of the BMPs is expected to drive a positive TBL-NPV when accounting for the financial, social and environmental impacts for Site 3 (Subbasin 260). The total TBL-NPV is $190,781 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The social NPV is the biggest driver of the positive results, namely through induced recreation via improved water quality estimated at $2,773,505 (Figure 2). The environmental NPV is the next largest generator of benefits for Site 3 (Subbasin 260) at $165,371, with the majority of the impact category stemming from vegetation sequestration (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 3 (Subbasin 260) | Net Present Value Over 50 Years Discounted at 3%



Autocase Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 4 (SUBBASIN 270) -

REPORT OVERVIEW

REPORT AUTHOR
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PREPARED FOR
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(SARA)

MAY 2021

Autocase
Economic Advisory

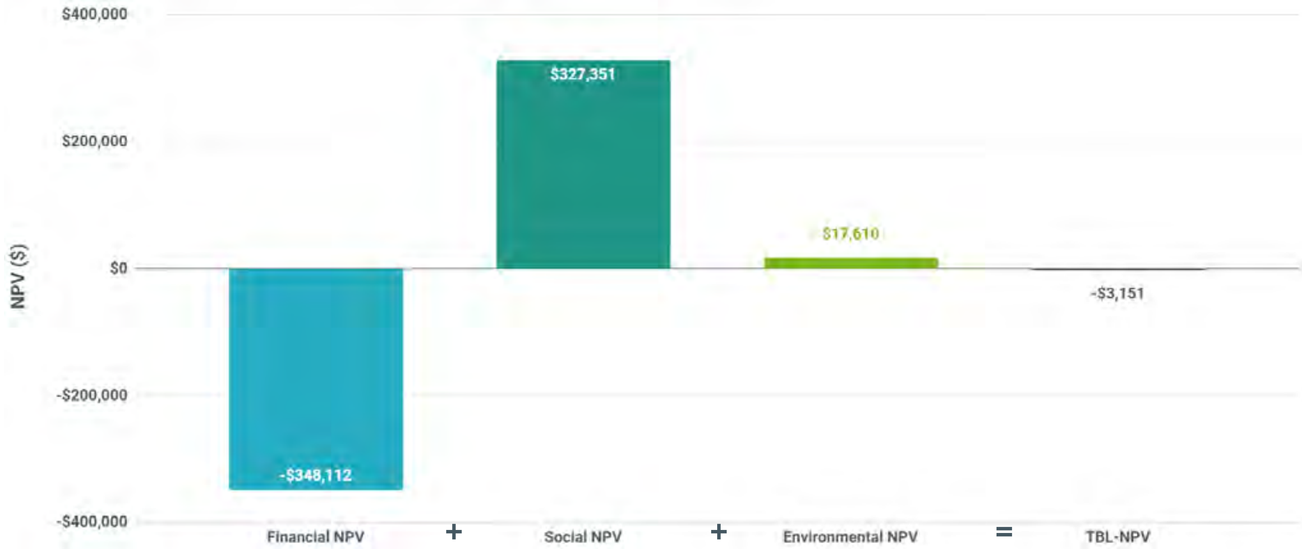
Table 1. Results for Site 4 (Subbasin 270) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$132,700
	Operations & Maintenance	-$161,900
	Replacement Costs	-$57,342
	Residual Value	$3,830
Social	Flood Risk	$72
	Education	$30,915
	Urban Heat Island	$930
	Open Space - Recreation	$190
	Water Quality - Induced Recreation	$295,244
Environmental	Air Pollution from Sequestration	$120
	Carbon Emissions from Sequestration	$9,860
	Trash	$6,074
	Water Quality - Pollutant Loading Reduction	$934
	Pollination	$622

Financial NPV	-$348,112
Social NPV	$327,351
Environmental NPV	$17,610
Triple Bottom Line-Net Present Value (TBL-NPV)	-$3,151

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

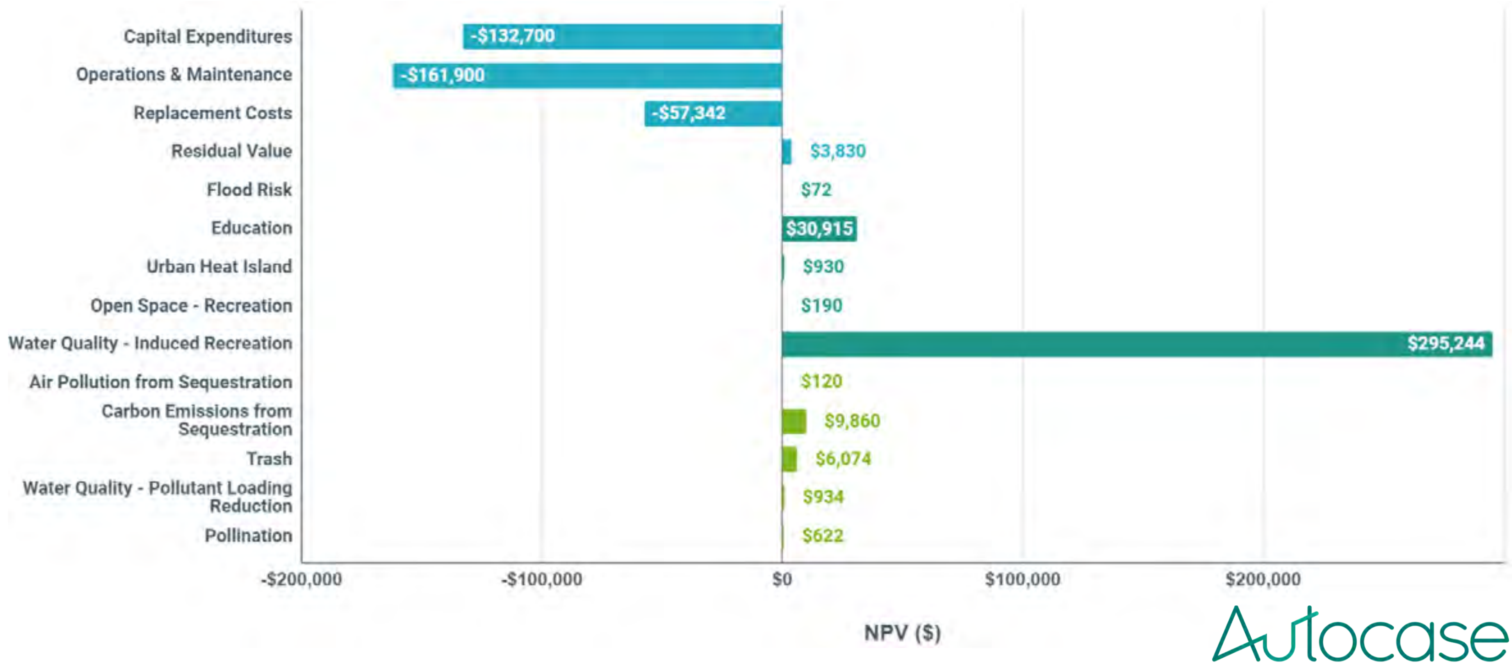
Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 4 (Subbasin 270) | Net Present Value Over 50 Years Discounted at 3%



The implementation of the BMPs is expected to drive a negative TBL-NPV when accounting for the financial, social and environmental impacts for Site 4 (Subbasin 270). The total TBL-NPV is -$3,151 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The financial NPV is the biggest driver of the negative results, namely through increased capital, operations and maintenance, and replacements costs estimated at approximately $348,112. The social NPV is the largest generator of benefits for Site 4 (Subbasin 270) at $327,351, with the majority of the impact category stemming from induced recreation via improved water quality (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 4 (Subbasin 270) | Net Present Value Over 50 Years Discounted at 3%



Autocase Economic Advisory

TRIPLE BOTTOM LINE- COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 5 (SUBBASIN 310) -

REPORT OVERVIEW

REPORT AUTHOR
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PREPARED FOR
SAN ANTONIO RIVER AUTHORITY (SARA)

MAY 2021

Autocase
Economic Advisory

Table 1. Results for Site 5 (Subbasin 310) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$155,000
	Operations & Maintenance	-$194,300
	Replacement Costs	-$68,835
	Residual Value	$4,600
Social	Flood Risk	$221
	Education	$30,915
	Urban Heat Island	$1,120
	Open Space - Recreation	$1,200
	Water Quality - Induced Recreation	$354,365
Environmental	Air Pollution from Sequestration	$150
	Carbon Emissions from Sequestration	$11,800
	Trash	$7,339
	Water Quality - Pollutant Loading Reduction	$1,027
	Pollination	$747

Financial NPV	-$413,535
Social NPV	$387,821
Environmental NPV	$21,063
Triple Bottom Line-Net Present Value (TBL-NPV)	-$4,651

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

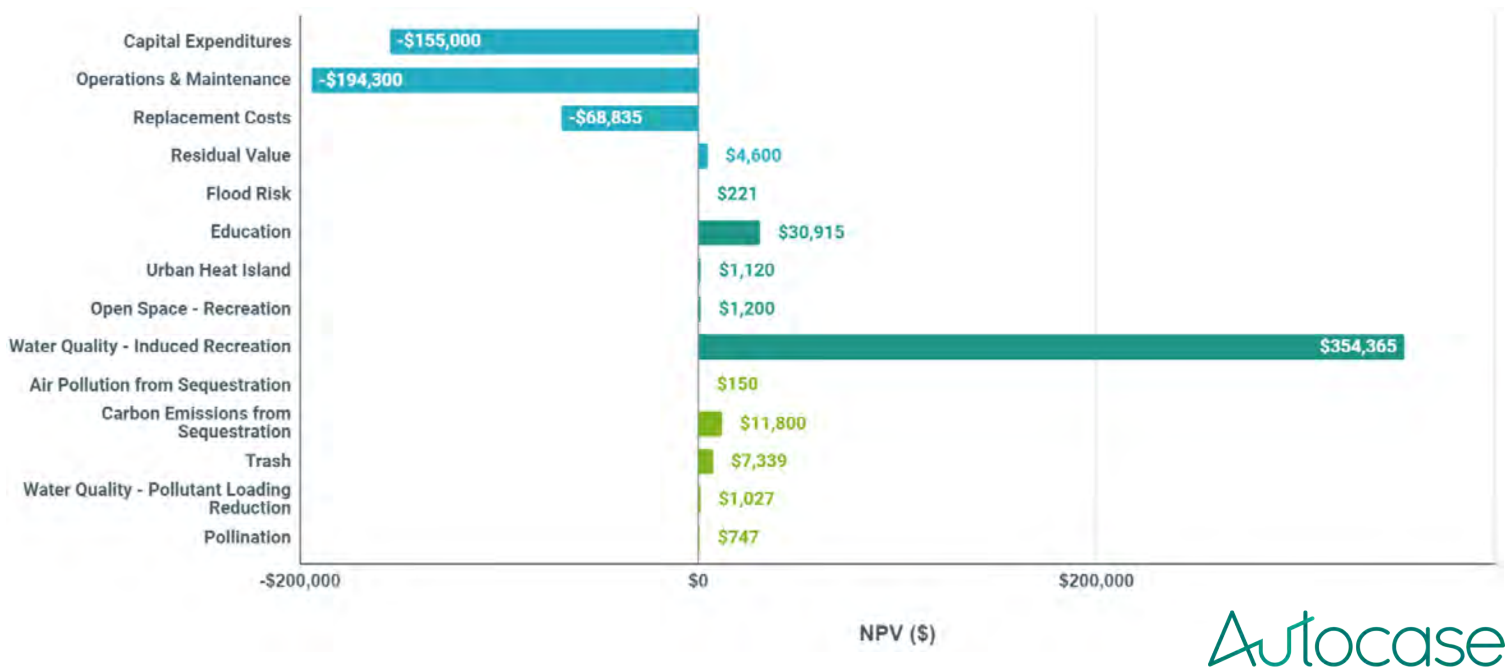
Autocase Economic Advisory

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 5 (Subbasin 310) | Net Present Value Over 50 Years Discounted at 3%

The implementation of the BMPs is expected to drive a negative TBL-NPV when accounting for the financial, social and environmental impacts for Site 5 (Subbasin 310). The total TBL-NPV is -$4,651 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The financial NPV is the biggest driver of the negative results, namely through increased capital, operations and maintenance, and replacements costs estimated at approximately $413,535. The social NPV is the largest generator of benefits for Site 5 (Subbasin 310) at $387,821, with the majority of the impact category stemming from induced recreation via improved water quality (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 5 (Subbasin 310) | Net Present Value Over 50 Years Discounted at 3%



Autocase
Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 6 (SUBBASIN 330) -

REPORT OVERVIEW

REPORT AUTHOR
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(BY IMPACT INFRASTRUCTURE, INC.)

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(SARA)

JUNE 2021

Autocase
Economic Advisory

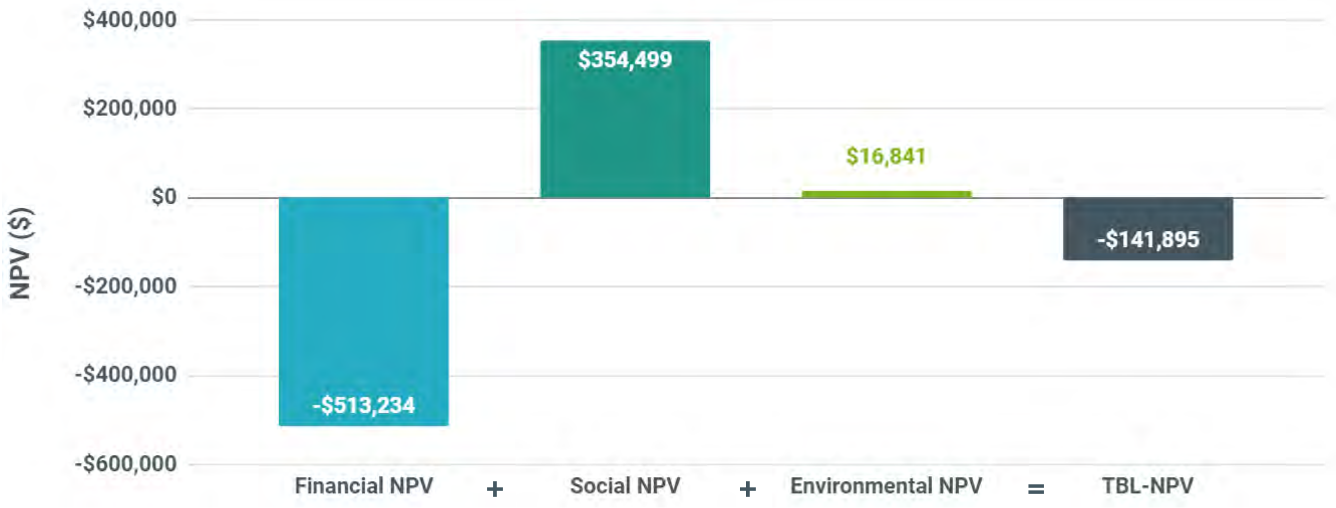
Table 1. Results for Site 6 (Subbasin 330) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$263,800
	Operations & Maintenance	-$185,400
	Replacement Costs	-$68,624
	Residual Value	$4,590
Social	Flood Risk	$93
	Education	$0
	Urban Heat Island	$1,110
	Open Space - Recreation	$0
	Water Quality - Induced Recreation	$353,296
Environmental	Air Pollution from Sequestration	$150
	Carbon Emissions from Sequestration	$11,800
	Trash	$2,784
	Water Quality - Pollutant Loading Reduction	$1,363
	Pollination	$744

Financial NPV	-$513,234
Social NPV	$354,499
Environmental NPV	$16,841
Triple Bottom Line-Net Present Value (TBL-NPV)	-$141,895

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

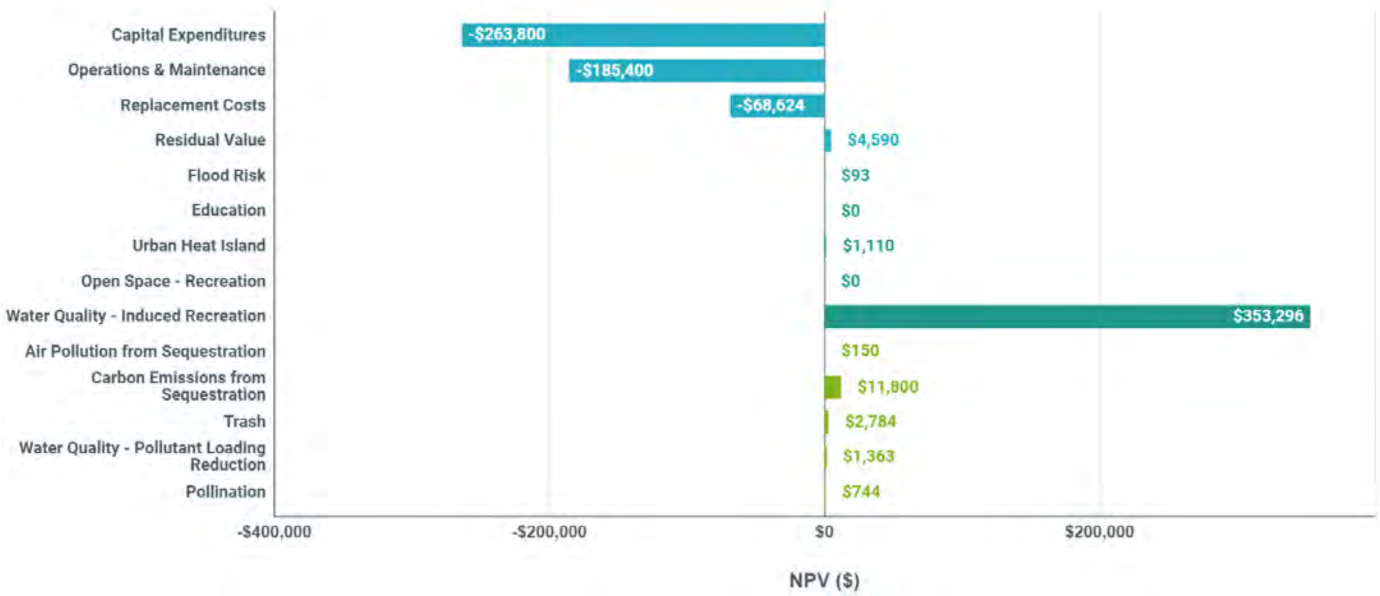
Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 6 (Subbasin 330) | Net Present Value Over 50 Years Discounted at 3%



The implementation of the BMPs is expected to drive a negative TBL-NPV when accounting for the financial, social and environmental impacts for Site 6 (Subbasin 330). The total TBL-NPV is -$141,895 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The financial NPV is the biggest driver of the negative results, namely through increased capital, operations and maintenance, and replacements costs estimated at approximately $513,234. The social NPV is the largest generator of benefits for Site 6 (Subbasin 330) at $354,499, with the majority of the impact category stemming from induced recreation via improved water quality (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 6 (Subbasin 330) | Net Present Value Over 50 Years Discounted at 3%



Autocase
Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 7 (SUBBASIN 420) -

REPORT OVERVIEW

REPORT AUTHOR
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PREPARED FOR
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(SARA)

MAY 2021

Autocase
Economic Advisory

Table 1. Results for Site 7 (Subbasin 420) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$181,900
Financial	Operations & Maintenance	-$240,600
Financial	Replacement Costs	-$89,051
Financial	Residual Value	$5,950
Social	Flood Risk	$221
Social	Education	$0
Social	Urban Heat Island	$1,440
Social	Open Space - Recreation	$0
Social	Water Quality - Induced Recreation	$458,359
Environmental	Air Pollution from Sequestration	$190
Environmental	Carbon Emissions from Sequestration	$15,300
Environmental	Trash	$9,366
Environmental	Water Quality - Pollutant Loading Reduction	$983
Environmental	Pollination	$966

Financial NPV	-$505,601
Social NPV	$460,020
Environmental NPV	$26,805
Triple Bottom Line-Net Present Value (TBL-NPV)	-$18,776

This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 7 (Subbasin 420) | Net Present Value Over 50 Years Discounted at 3%

The implementation of the BMPs is expected to drive a negative TBL-NPV when accounting for the financial, social and environmental impacts for Site 7 (Subbasin 420). The total TBL-NPV is -$18,776 when implementing the GSI design over the baseline managed turf conditions (Figure 1). The financial NPV is the biggest driver of the negative results, namely through increased capital, operations and maintenance, and replacements costs estimated at approximately $505,601. The social NPV is the largest generator of benefits for Site 7 (Subbasin 420) at $460,020, with the majority of the impact category stemming from induced recreation via improved water quality (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 7 (Subbasin 420) | Net Present Value Over 50 Years Discounted at 3%

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

SITE 8 (SUBBASIN 560) -

REPORT OVERVIEW

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PREPARED FOR
SAN ANTONIO RIVER AUTHORITY (SARA)

MAY 2021

Autocase Economic Advisory

Table 1. Results for Site 8 (Subbasin 560) | Net Present Value Over 50 Years Discounted at 3%

	Impact	Lifetime NPV
Financial	Capital Costs	-$2,481,000
	Operations & Maintenance	-$811,100
	Replacement Costs	-$284,379
	Residual Value	$19,000
Social	Flood Risk	$647
	Education	$0
	Urban Heat Island	$4,620
	Open Space - Recreation	$0
	Water Quality - Induced Recreation	$767,218
Environmental	Air Pollution from Sequestration	$600
	Carbon Emissions from Sequestration	$49,000
	Trash	$29,863
	Water Quality - Pollutant Loading Reduction	$3,194
	Pollination	$3,087

Financial NPV	-$3,557,479
Social NPV	$772,485
Environmental NPV	$85,744
Triple Bottom Line-Net Present Value (TBL-NPV)	-$2,699,250

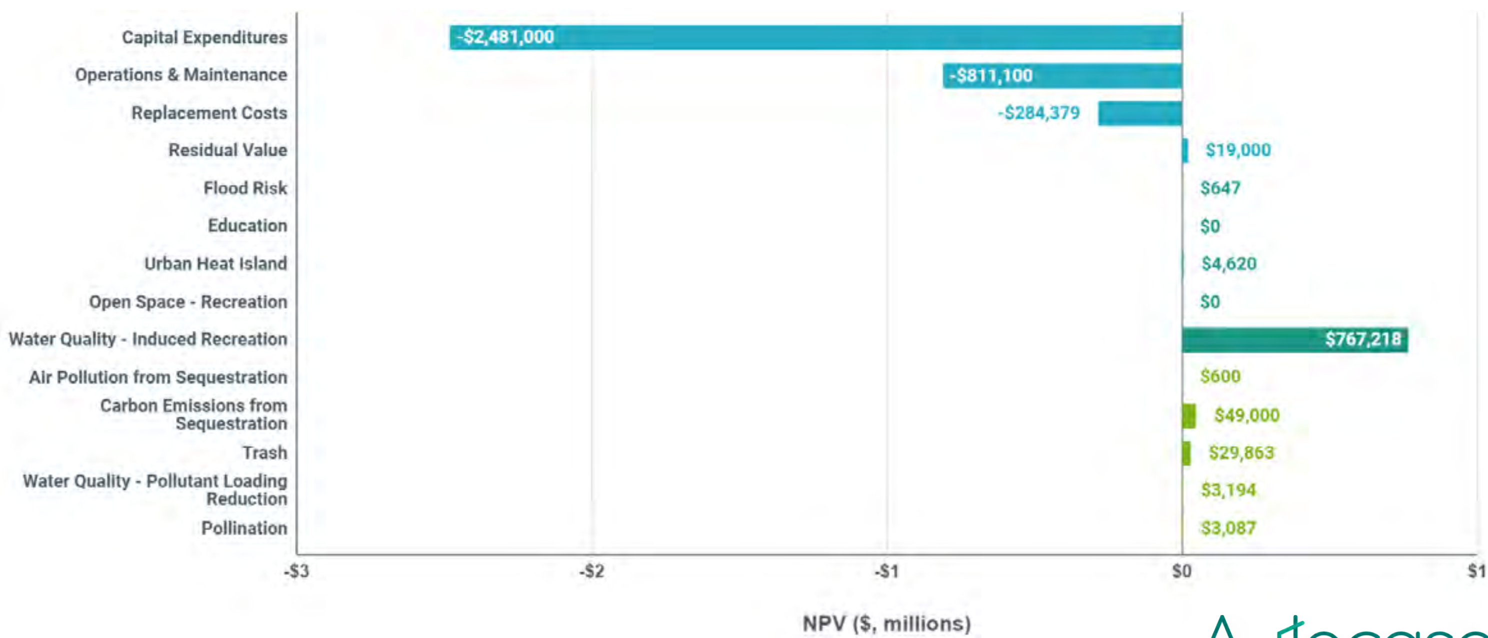
This report analyzes the SARA Green Stormwater Infrastructure (GSI) Master Plan that comprises of a redevelopment of 8 sites with GSI Best Management Practices (BMPs). The site redevelopments are expected to have a construction duration of 1 year, along with an operations duration of 50 years, dictating the timeline of the analysis. The modeling included best-available regional climate change projections affecting rainfall and temperature data using Representative Carbon Pathway (RCP) 4.5. Using a discount rate of 3%, all the costs and benefits that accrue over the life of the project were discounted back to current dollars in order to provide the Triple Bottom Line-Net Present Value (TBL-NPV). Net Present Value (NPV) is used to measure all future cash flows of a project and discount them back to current dollars to allow for comparison of all site redevelopments on an equal footing.

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For Site 8 (Subbasin 560) | Net Present Value Over 50 Years Discounted at 3%

The implementation of the BMPs is expected to drive a negative TBL-NPV when accounting for the financial, social and environmental impacts for Site 8 (Subbasin 560). The total TBL-NPV is -$2.70 million when implementing the GSI design over the baseline managed turf conditions (Figure 1). The financial NPV is the biggest driver of the negative results, namely through increased capital, operations and maintenance, and replacements costs estimated at approximately $3.56 million. The social NPV is the largest generator of benefits for Site 8 (Subbasin 560) at $772,485, with the majority of the impact category stemming from induced recreation via improved water quality (Figure 2).

A technical appendix containing the site inputs and methodologies used in the SARA GSI Triple Bottom Line-Cost Benefit Analysis (TBL-CBA) can be found at this link.

Figure 2. Comparison of the Expected NPV of each Category of Results For Site 8 (Subbasin 560) | Net Present Value Over 50 Years Discounted at 3%



Autocase Economic Advisory

TRIPLE BOTTOM LINE-COST BENEFIT ANALYSIS

THE SAN ANTONIO RIVER AUTHORITY GREEN STORMWATER INFRASTRUCTURE MASTER PLAN

TECHNICAL APPENDIX

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PREPARED FOR
SAN ANTONIO RIVER AUTHORITY
(SARA)

JUNE 2021

Table of Contents

About

The San Antonio River Authority (SARA) received US Environmental Protection Agency (EPA) funding through the Texas Commission on Environmental Quality (TCEQ) to create a Green Stormwater Infrastructure (GSI) Master Plan for portions of the Upper San Antonio River Watershed. The subject of this assessment is a suite of eight sites, currently characterized as turf-covered, that were modeled for potential GSI Best Management Practices (BMPs) implementation. The evaluation was constructed with a multidisciplinary team of engineers, landscape ecologists, planners, and economists.

An enhanced Cost Benefit Analysis (CBA) approach, also referred to as Triple Bottom Line-Cost Benefit Analysis (TBL-CBA), was used to value the impacts associated with each site. TBL-CBA is an evidenced-based economic method that combines CBA and Life Cycle Cost Analysis (LCCA) across the Triple Bottom Line (TBL) to weigh the costs and benefits incurred to project stakeholders. It expands the traditional financial analysis (capital and operations and maintenance costs) to account for social and environmental performance as well. It aims to quantify, in monetary terms, as many of the costs and benefits of the project as possible and convert them all into a present day dollar value representing the Net Present Value (NPV) of the project. The Triple Bottom Line-Net Present Value (TBL-NPV) of the sites is used to compare relative benefits and costs that accrue over their lifetime.

The underlying modelling to value the numerous impacts of the proposed Green Stormwater Infrastructure is complex. As such, an Executive Summary, individual report summaries and a Technical Appendix are available to readers. This Technical Appendix provides interested readers with a comprehensive and transparent understanding of the detailed methodologies, data and sources employed in this analysis. A more detailed set of inputs are also presented, along with structure and logic diagrams to illustrate the modelling concepts used in this analysis. The Executive Summary aims to cater to a general reader's understanding by presenting high level conceptual overviews of how each impact is calculated, along with their lifetime NPV.

Prepared By:

Autocase Economic Advisory

Prepared For:

San Antonio River Authority

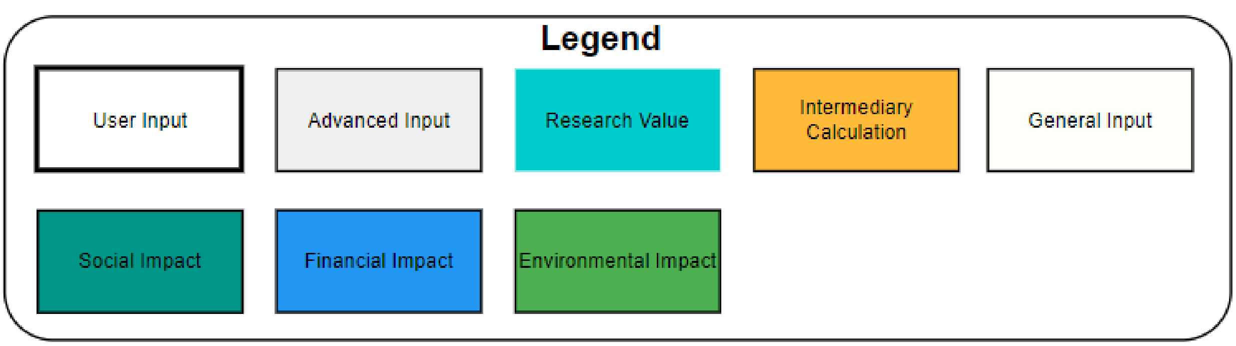
Project Parameters

SARA supplied the modeled hydrological simulation results to Autocase, assumed a 50-year BMP operational life expectancy, and requested a financial assessment period from 2022 to 2072 assuming a one-year BMP site installation period beginning in August 2022. Annual cash flows (benefits and costs) are accounted for throughout the entire study period. The modeling included best-available regional climate change projections affecting rainfall and temperature data using the Representative Carbon Pathway (RCP) 4.5. RCP 4.5 is a mild climate scenario where global action on climate change means that emissions peak around 2040, then begin to decline thereafter. To discount the future cash flows into today's dollars, a real discount rate of 3% was selected for the analysis and presented the economic impacts in terms of the NPV. By utilizing the real discount rate across the economic analysis, annual cash flows are not required to be inflated as this discount rate is net of expected annual inflation.

Methodologies

This section briefly describes the methods used to monetize the potential impacts of GSI BMP installation on the identified sites. Financial impacts reflect the changes accrued to the property owner in the form of upfront, operational and replacement costs, as well as any remaining residual value of the asset at the end of the project duration. Social impacts are derived from the BMP land cover types, which affect both the ability to retain stormwater and in turn mitigate flood risk, along with urban heat island impacts and increased induced recreation along the San Antonio River via improved water quality. Environmental impacts stem from the positive externalities attributed to the BMP installation. These benefits include increased sequestration of both carbon emissions and other broader air pollutants, improvements in the water quality from reduced pollutant loads, as well as any pollination accrued from having a more diverse and potentially higher growth vegetation on site. A link to the summary findings of that analysis can be found here (Autocase, 2021).

The method descriptions are accompanied by a Structure and Logic (S&L) diagram to visually depict the underlying calculations of the economic models. The legend below outlines the various impacts and input types included in such diagrams.



Financial Impacts

Life Cycle Cost Analysis (LCCA)

The installation of BMPs allows for greater inflow and infiltration of rainfall and may avoid the need for costly gray infrastructure replacements and investments to San Antonio's separate storm sewer system due to the reduction of stormwater conveyed during large storm events. Although these avoided investments are important factors to consider, due to data limitations in cost estimations this proposed efficiency remains a purely qualitative component of the analysis. Other than the managed turf design, the LCCA components of this analysis do not consider financial expenditures for any type of alternative GSI mitigation strategy in the base case relative to the BMP design.

Capital Expenditures

Capital expenditure (Capex) is the upfront cost of the project. Capital costs were estimated for each BMP by SARA. The capital expenditures were assumed to be evenly distributed across the construction period.

Operations and Maintenance Costs

Operations and maintenance (O&M) costs are those that occur yearly throughout the life of the project. Values are discounted to produce a present value of the costs.

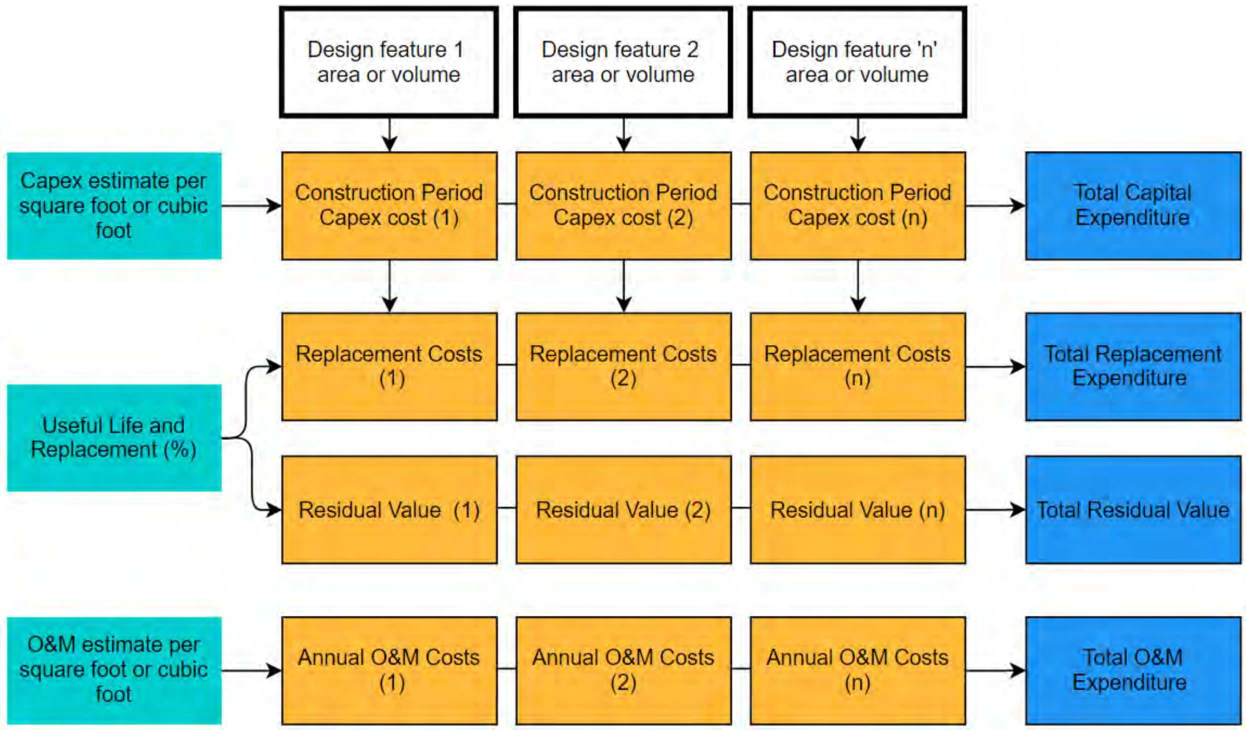
Regularly maintaining BMPs ensures their desired function is achieved, and overall is critical to the efficiency of their water infiltration capacity from stormwater runoff. O&M costs for the design BMP installations were estimated and provided by SARA. This analysis assumes any managed turf in the base case, is converted to unmanaged practices in the design case, offering marginal cost savings from regularly maintaining the landscape through mowing and herbicide applications. The avoided O&M costs (from a switch of managed turf to unmanaged BMPs) were estimated using Autocase's cost database for landscaping site features.

Replacement Costs

Elements of greening projects need to be replaced at some point, and feature types have different lifespans, as well as different costs of replacement at the end of their operating lives. Autocase quantifies these costs as the lifetime "Replacement Costs" of each feature. Replacement costs for features are estimated whenever the expected operating duration of the infrastructure exceeds the lifespan of a feature. Replacement costs are then combined with the expected lifespans of each feature type and the operating life of the project to quantify the expected total replacement costs. Replacement costs for the design BMPs were estimated by SARA.

Residual Value

At the end of the project some of the features may still have value. This value is captured as residual value using linear depreciation over the lifespan of the feature by Autocase. The remaining value of the features at the end of the projects' timelines is considered an asset and yields a positive financial value.



References

- The Capex, O&M costs, and replacement costs/schedules for the BMP areas were provided by SARA.
- Cheng, H., Hu, Y., & Reinhard, M. (2014). Environmental and health impacts of artificial turf: a review. Environmental science & technology, 48(4), 2114-2129. Retrieved from: https://core.ac.uk/download/pdf/71730025.pdf.
- Hall, C. R., Sorochan, J. C., & Samples, T. (2005). Costs of managing a bermudagrass football field in Tennessee. Univ. Tenn. Ag. Ext. Factsheet, 651. Retrieved from: https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1019&context=utk_agexcomhort.
- San Antonio River Authority (SARA). (2019). San Antonio River Basin Low Impact Development Technical Design Guidance Manual. Second Edition. Retrieved from: https://www.sariverauthority.org/sites/default/files/2019-08/SARB%20LID%20Technical%20Design%20Manual%202nd%20Edition.pdf.

- Uhlman, B., Diwan, M., Dobson, M., Sferrazza, R., & Songer, P. (2010). Synthetic Turf, Eco-Efficiency Analysis Final Report. Florem park NJ, BASF Corporation. NSF Protocol P, 352. Retrieved from: https://d2evkimvhatqav.cloudfront.net/documents/Synthetic_Turf_EEA_Study_Verification_Final.pdf.
- U.S. Environmental Protection Agency. (1995). Appendix 8. Examples of Natural Landscaping Installation and Maintenance Cost. Retrieved from: https://archive.epa.gov/greenacres/web/pdf/appendix8.pdf.
- U.S. Environmental Protection Agency. (2019). July 2019 Report: Tire Crumb Rubber Characterization: Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan - Final Report Part 1 - Volume 2. Retrieved from: https://www.epa.gov/sites/production/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_2.pdf.

Social Impacts

Flood Risk

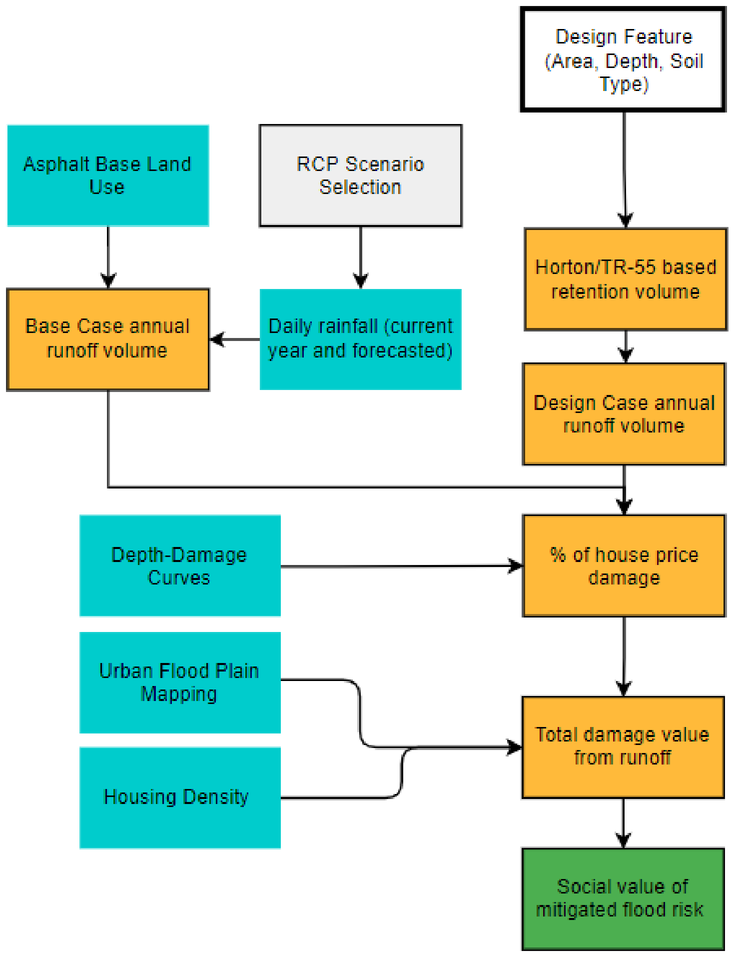
Increased acres of vegetation, such as bioretention features and vegetated detention basins, can positively influence the community through the reduction of localized flood risk. Using GSI BMP features for stormwater management can reduce the surface runoff volume that impacts residential properties located in the city's flood plain.

The flood risk model values the benefits of reduced runoff water in terms of avoided property damage. As a first step, the floodplain is assessed as the percentage of the City area that would be impacted during a flood storm. Then, the level of runoff is calculated in a flood situation. The level of runoff gives an indication to the volume of water that is expected to impact neighboring areas in a storm event.

Feature specific inputs such as storage volume, ponding depth, depth of coverage of materials, empty space, infiltration rate, and reduction factor (as applicable per feature) are responsible for calculating runoff depth. The flood risk model divides 24 hours of daily rainfall into 30-minute brackets. The model also accounts for changes in future precipitation due to climate change by using RCP 4.5 rainfall projections.

Depending on the green infrastructure investment, infiltration over the project period is calculated using the minimum and maximum infiltration rates along with the corresponding reduction factor using Horton's equation. The infiltration reduction factor is the rate at which the level of infiltration shifts from maximum to minimum within 24 hours of rainfall. Stormwater retention capacity in Horton's model also incorporates ponding depths for relevant features. Ponding depth can be defined as the conical dip in the LID surface that has the capacity to accumulate and store stormwater. Ponding depth and the type of soil affect the feature's capacity to absorb rainwater and reduce levels of surface runoff.

Given the above calculations of runoff, the model calculates a monetary valuation of reduced flooding across the City at a high-level. The value at risk within the floodplain zone is dependent on housing density, typical property value in the area, and the City's total flood plain (as a percentage).



References

- Canadian Centre for Climate Modelling and Analysis (CCCma). (2017). CanESM2 model: The Fourth Generation Global Climate Model. Retrieved from: http://climate-modelling.canada.ca/data/data.shtml.
- Hanson, L. S. & R. Vogel. (2008). The Probability Distribution of Daily Rainfall in the United States. Retrieved from http://engineering.tufts.edu/cee/people/vogel/documents/DailyRainfall.pdf.

- Nowak, D. J. & E. J. Greenfield. (2012). Tree and Impervious Cover Change in U.S. Cities. Retrieved from http://www.itreetools.org/Canopy/resources/Tree_and_Impervious_Cover_change_in_US_Cities_Nowak_Greenfield.pdf.
- Pielke, Jr., R.A., M.W. Downton, & J.Z. Barnard Miller. (2002). Flood Damage in the United States, 1926-2000: A Reanalysis of National Weather Service Estimates. Retrieved from http://www.flooddamagedata.org/flooddamagedata.pdf.
- Schueler, T. R. (1987). Controlling urban runoff: A practical manual for planning and designing urban BMPs. Water Resources Publications. Retrieved from: https://www.mwcog.org/documents/1987/07/01/controlling-urban-runoff-bmp-stormwater/.
- TR-55: Conservation Engineering Division, Natural Resources Conservation Service, United States Department of Agriculture. (1986). Urban Hydrology for Small Watersheds – TR-55. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.
- U.S. Environmental Protection Agency. (2009). Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects. Retrieved from: https://www.epa.gov/sites/production/files/2015-08/documents/epa_swm_guidance.pdf.
- Wing, O. E., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. Environmental Research Letters, 13(3), 034023. Retrieved from: https://iopscience.iop.org/article/10.1088/1748-9326/aaac65/pdf.

Urban Heat Island Effect

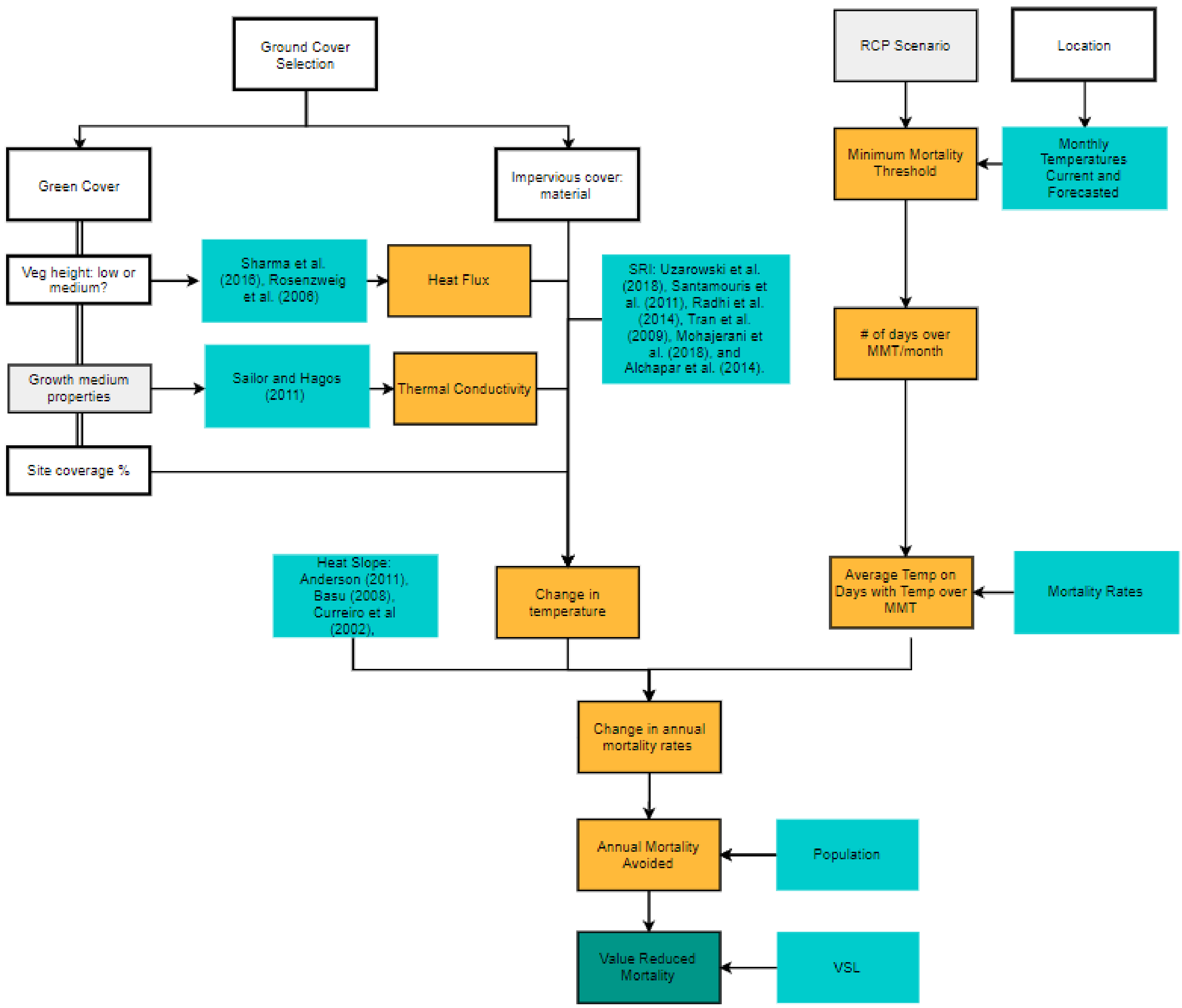
Improving vegetated land cover and increasing and scope of vegetation reduces ambient temperatures as it increases the albedo of the project location, effectively cooling the ambient surroundings near green space. This decrease in ambient temperature is responsible for providing respite from extreme summer temperatures. This translates into a social benefit – especially in a hot environment in terms of reduced heat stress and stroke induced mortality.

To calculate mortality benefits between the base and design cases, Solar Reflectivity Index (SRI) and heat flux are compared. These differences in values impact the average forecasted temperature and reduce average mortality rate from a literature derived mortality to temperature relationship across North America, which occurs when the threshold minimum mortality temperature (MMT) in the region is exceeded (Curriero et al., 2002).

The temperature data used to run the urban heat island benefits is sourced from the Canadian Center for Climate Modelling and Analysis (2017). Temperature data within this source is forecasted from 2020 to 2100 from RCP 4.5 across granular location grids covering 25x25 square kilometers.

As minimum mortality values remain stable, the average number of days over this threshold rises, and the difference in temperature each project contributes to the area of San Antonio is attributed to a number of lives saved by the relationship between death and temperature changes.

This reduced mortality is monetized with the standard method of Value of Statistical Life (U.S. Environmental Protection Agency, 2010), where internationally accepted standards are employed to derive the value of a human life with respect to willingness to pay functions of loss of health, bodily issues, and experimentally derived risk taking behavior of people.



References

- Alchapar, N. L., Correa, E. N., & Cantón, M. A. (2014). Classification of building materials used in the urban envelopes according to their capacity for mitigation of the urban heat island in semiarid zones. Energy and Buildings, 69, 22-32. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0378778813006580.
- Anderson, G. B., & Bell, M. L. (2011). Heat waves in the United States: mortality risk during heat waves and effect modification by heat wave characteristics in 43 US communities. Environmental health perspectives, 119(2), 210-218. Retrieved from: https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1002313.
- Basu, R., Feng, W. Y., & Ostro, B. D. (2008). Characterizing temperature and mortality in nine California counties. Epidemiology, 138-145. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.415.2546&rep=rep1&type=pdf.
- Canadian Centre for Climate Modelling and Analysis (CCCma). (2017). CanESM2 model: The Fourth Generation Global Climate Model. Retrieved from: http://climate-modelling.canada.ca/data/data.shtml.
- Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999-2019 on CDC WONDER Online Database, released in 2020. Data are from the Multiple Cause of Death Files, 1999-2019, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/ucd-icd10.html.
- Curriero, F. C., Heiner, K. S., Samet, J. M., Zeger, S. L., Strug, L., & Patz, J. A. (2002). Temperature and mortality in 11 cities of the eastern United States. American journal of epidemiology, 155(1), 80-87. Retrieved from: https://academic.oup.com/aje/article/155/1/80/134292.
- Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., ... & Tong, S. (2014). Global variation in the effects of ambient temperature on mortality: a systematic evaluation. Epidemiology (Cambridge, Mass.), 25(6), 781. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4180721/.
- Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. Journal of environmental management, 197, 522-538. Retrieved from: https://www.academia.edu/download/53441691/The_UHI_effect_with_reference_to_Asphalt_Concrete.pdf.
- Radhi, H., Fikry, F., & Sharples, S. (2013). Impacts of urbanisation on the thermal behaviour of new built up environments: A scoping study of the urban heat island in Bahrain. Landscape and Urban Planning, 113, 47-61. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0169204613000200.
- Rosenzweig, C., Solecki, W., & Slosberg, R. (2006). Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces. A report to the New York State Energy Research and Development Authority. Retrieved from:

https://usclimateandhealthalliance.org/post_resource/mitigating-new-york-citys-heat-island-with-urban-forestry-living-roofs-and-light-surfaces/.

- Sailor, D. J., & Hagos, M. (2011). An updated and expanded set of thermal property data for green roof growing media. Energy and buildings, 43(9), 2298-2303. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0378778811002283.
- Santamouris, M., Synnefa, A., & Karlessi, T. (2011). Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions. Solar Energy, 85(12), 3085-3102. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0038092X10004020.
- Sharma, A., Woodruff, S., Budhathoki, M., Hamlet, A. F., Chen, F., & Fernando, H. J. S. (2018). Role of green roofs in reducing heat stress in vulnerable urban communities—A multidisciplinary approach. Environmental Research Letters, 13(9), 094011. Retrieved from: https://iopscience.iop.org/article/10.1088/1748-9326/aad93c/pdf.
- Tran, N., Powell, B., Marks, H., West, R., & Kvasnak, A. (2009). Strategies for design and construction of high-reflectance asphalt pavements. Transportation research record, 2098(1), 124-130. Retrieved from: http://web-ha.eng.auburn.edu/research/centers/ncat/files/reports/2009/rep09-02.pdf.
- U.S. Census Bureau. (2019). 2019: ACS 5-Year Estimates Detailed Tables. Retrieved from: https://data.census.gov/cedsci/table?q=B01003&tid=ACSDT5Y2019.B01003&hidePreview=false.
- U.S. Environmental Protection Agency. (2010). Guidelines for preparing economic analyses. Retrieved from: https://www.epa.gov/sites/production/files/2017-08/documents/ee-0568-50.pdf.
- Uzarowski, L., Eng, P., Rizvi, L. R., Manolis, L. S., & Paving, C. (2018). Reducing Urban Heat Island Effect by Using Light Coloured Asphalt Pavement. In TAC 2018: Innovation and Technology: Evolving Transportation-2018 Conference and Exhibition of the Transportation Association of Canada. Retrieved from: https://www.tac-atc.ca/sites/default/files/conf_papers/uzarowskil_-_reducing_urban_heat_island_effect_using_lcap.pdf.

Open Space - Recreation

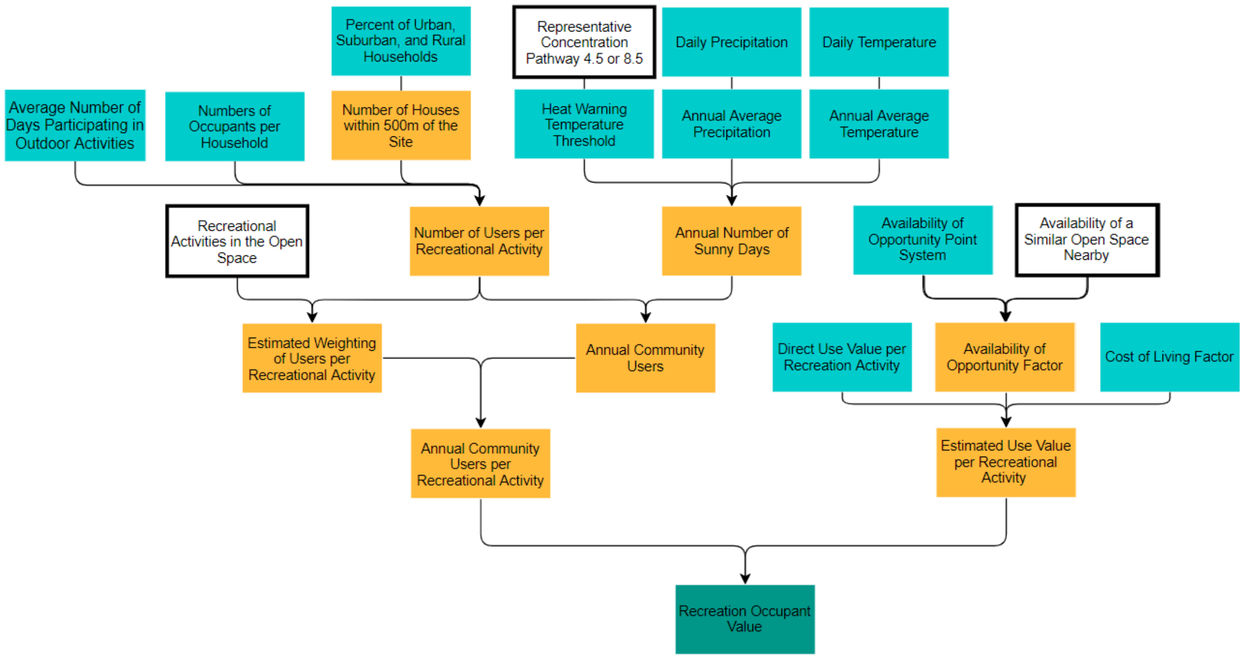
Investments in open space can provide the opportunity for community members in the vicinity of each project to participate in recreation activities. Literature suggests that recreational activities in open spaces are valued by individuals as they would otherwise have to pay to participate in similar activities in commercial facilities with admission fees.

To calculate the local recreation users around the project locations, the expected number of residential dwellings (U.S. EPA, 2020; Bierwagen et al., 2010), within an area using a 500 meter radius around the site, is combined with population density values (US Census Bureau, 2019) to estimate the number of potential residential recreation users within the project radius.

The US EPA's ICLUS (Integrated Climate and Land Use Scenarios) tool is used to estimate the base case or existing green space/park area within the radius. To calculate the difference between the base and design cases, Autocase estimates the percent addition of green space (relative to the existing green space) available to the community to recreate. BMPs encourage recreation since they enhance natural beauty by incorporating diverse vegetation and attracting pollinators and other wildlife. This increase in total BMP acreage thus incentives land-based recreation activities (birdwatching, viewing nature, etc) that otherwise would not be available to local users.

To estimate the increase in recreation user days from a marginal increase in green space, annualized days of participation for the land-based recreational activities (noted above) are estimated (White et al., 2016). With the total annual number of recreation days per user known, the percent increase in local green space is attributed to the number of days users are expected to recreate. For example, assuming a 5% increase in greenspace and that people recreate in nature on average 163 days per year, we could attribute approximately an 8.15 day increase in recreation by the local community (on an annual basis).

Taking the number of days a user would recreate, the incremental number of community users who would recreate at the BMP location is calculated. Autocase Advisory applies a cost of living index (Numbeo 2018) and inflation to the per activity direct use values (TTPL 2008a; 2008b) to determine the value per activity for San Antonio. The annual number of community members that use the open space are combined with the use weighting per activity (TTPL 2008a; 2008b) to estimate the annual number of users per activity. The product of the value per activity and the annual number of users per activity is summed across the activities selected in the open space. This annual value is summed over the operational period to determine the Open Space - Recreation benefit. This valuation only applies to Sites 1, 2, 3, 4, and 5 due to the availability and direct usability of these open spaces to the public at large.



References

- Bierwagen, B. G., Theobald, D. M., Pyke, C. R., Choate, A., Groth, P., Thomas, J. V., & Morefield, P. (2010). National housing and impervious surface scenarios for integrated climate impact assessments. Proceedings of the National Academy of Sciences, 107(49), 20887-20892. Retrieved from: https://www.pnas.org/content/pnas/107/49/20887.full.pdf.
- Numbeo. (2018). Cost of Living Index by City 2018. Retrieved from: https://www.numbeo.com/cost-of-living/rankings.jsp?title=2018.
- The Trust for Public Land's (TTPL) Center for City Park Excellence. (2008a). How Much Value Does the City of Philadelphia Receive from its Park and Recreation System? Retrieved from: http://cloud.tpl.org/pubs/ccpe-boston-park-value-report.pdf
- The Trust for Public Land's (TTPL) Center for City Park Excellence. (2008b). How Much Value Does the City of Philadelphia Receive from its Park and Recreation System? Retrieved from: https://www.tpl.org/sites/default/files/cloud.tpl.org/pubs/ccpe_PhilaParkValue_Calculators.pdf.
- U.S. Census Bureau. (2019). Quick Facts, San Antonio city, Texas. Retrieved from: https://www.census.gov/quickfacts/fact/table/sanantoniocitytexas/PST045219
- U.S. Environmental Protection Agency (EPA). (2020). Integrated Climate and Land Use Scenarios (ICLUS). Retrieved from: https://iclus.epa.gov/#v=map&b=gray-vector&l=4!8!9!6&x=-100.27!-77.03!-75.55!-122.4&y=39.87!38.7!40.43!37.78&m=1&s=ssp2!ssp2!ssp2!ssp2&d=land_use!land_use!land_use!land_use&o=giss_e2_r!giss_e2_r!giss_e2_r!giss_e2_r&a=0&z=2.

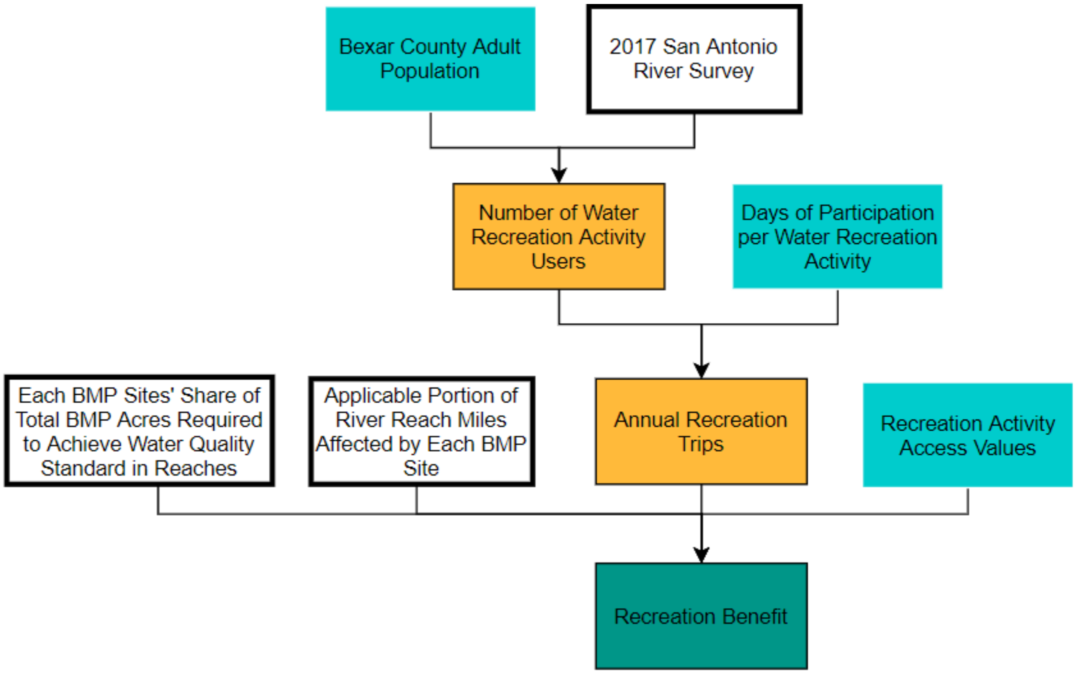
- White, E., Bowker, J. M., Askew, A. E., Langner, L. L., Arnold, J. R., & English, D. B. (2016). Federal outdoor recreation trends: effects on economic opportunities. US Department of Agriculture, Forest Service, Pacific Northwest Station. 46 p., 945. Retrieved from: https://www.fs.fed.us/pnw/pubs/pnw_gtr945.pdf

Water Quality - Induced Recreation

Capturing stormwater and runoff before it enters surface waters also captures pollutants. By passively removing these pollutants through BMPs including improved vegetated land cover, the potential of recreation activities associated with surface waters increases. Though individual BMPs are unlikely to materially change the quality of surface water, together they are able to influence the water quality of the surface water body downstream.

A primary objective of the GSI Master Plan is to reduce stormwater runoff pollution flowing into the San Antonio River, not only to protect essential and significant life in water, but also to achieve Texas Surface Water Quality Standards suitable for both direct (swimming) and in-direct (non-motorized boating) recreation users (as outlined by the EPA). SARA has prepared an extensive Master Plan accounting for all river reaches flowing through the San Antonio River that outlines the area of BMP installations required in each subbasin to achieve this water quality standard. The 8 sites identified in this analysis are assumed to incrementally improve water recreation, when scaled relative to the total BMP acreage required for achieving the standard. As such, benefits are assigned in the form of marginally inducing water-based recreation along the San Antonio River. These results must be carefully interpreted as the incremental improvement in water quality towards the EPA standard, such that they do not imply that recreation would immediately become available to those particular river segments. Instead, the results reflect the incremental value of induced water recreation provided by each site if the GSI Master Plan was implemented across all subbasins draining to the San Antonio River above its confluence with Salado Creek. The NPV results for each site are scaled based on the contribution of the BMP site area to the total BMP acreage identified in the GSI Master Plan required to achieve Texas Surface Water Quality Standards.

To calculate water-based recreation benefits, the number of adults who would recreate in or around the San Antonio River system, if improvements to water quality occurred, is determined using public opinion surveys (SARA, 2017). Using population estimates (U.S. Census Bureau, 2019) and days of participation for specific recreation activities (White et al., 2016), the annual number of recreation trips is calculated. This increased number of water-based recreation trips is monetized using EPA (2017) guidance on water recreation activity access values, which is then assigned to each site based on the share of the sites' BMP(s) in the total BMP acres required to achieve water quality standard in the reaches, and the applicable portion of the miles of river reach that are affected by that site. It should be noted that this impact is applicable to watershed wide recreation (by assuming all BMPs outlined in the SARA GSI Master Plan are implemented), as compared to open space recreation that is land-based and specific to the immediate areas around the proposed BMP sites.



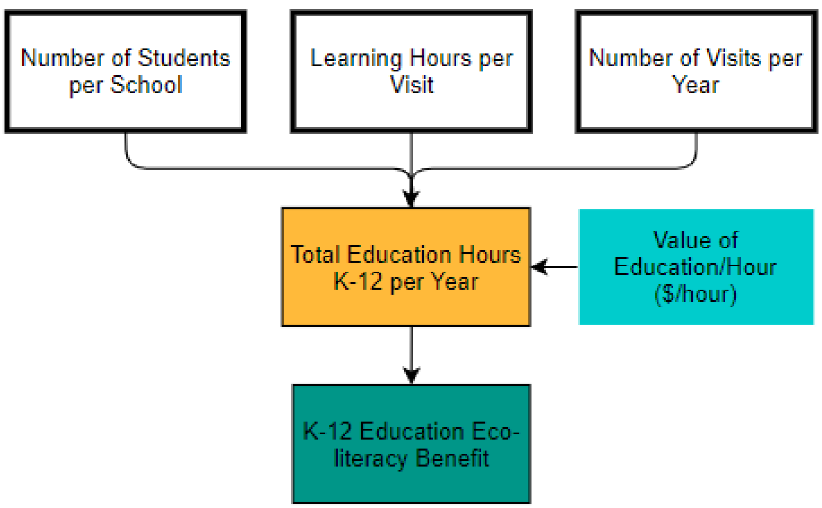
References

- San Antonio River Authority (SARA). (2017). 2017 San Antonio River Survey. Provided via personal communications (emails) with SARA.
- U.S. Census Bureau. (2019). Quick Facts, Bexar County, Texas. Retrieved from: https://www.census.gov/quickfacts/fact/table/bexarcountytexas/PST045219
- U.S. Environmental Protection Agency (EPA). (2017). Estimating the Value of Water: A Literature Review. Retrieved from: https://www.epa.gov/npdes/estimating-value-water-literature-review
- White, E., Bowker, J. M., Askew, A. E., Langner, L. L., Arnold, J. R., & English, D. B. (2016). Federal outdoor recreation trends: effects on economic opportunities. US Department of Agriculture, Forest Service, Pacific Northwest Station. 46 p., 945. Retrieved from: https://www.fs.fed.us/pnw/pubs/pnw_gtr945.pdf

Education

GSI BMP investments located at or near schools often offer unique learning opportunities and support education for students, children, and adults alike. Improving eco-literacy and the general public's awareness is valuable and part of a suite of tools to change behavior towards sustainable action. Students learn about water management, natural habitats, and innovative green engineering projects.

The learning aspect of BMP projects is valued through the equivalent cost of classroom education for K-12 in San Antonio (U.S. Department of Education, 2016), with the assumption that education within the classroom is equivalent to education at the project site. Education system budgets are apportioned per student in each corresponding state to generate a willingness to pay valuation for education. Visit rates are estimated from the number of students at each school, with a corresponding lesson per year. The estimated number of student hours spent on-site is multiplied by the cost of educating a student per hour to give us the educational value for the time students spend at the project site. This valuation only applies to Sites 1, 3, 4, and 5 due to the proximity and availability of these BMP sites to school facilities.



References

- Estimates for learning hours per visit and number of visits per year were provided by SARA GSI.
- U.S. Department of Education National Center for Education Statistics (NCES). (2018). School and Staffing Survey (SASS): Table 7. Average class size in public primary schools, middle schools, high schools, and schools with combined grades, by classroom type and state: 2011–12. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass1112_2013314_t1s_007.asp.

- U.S. Department of Education National Center for Education Statistics (NCES). (2018). State Education Practices (SEP): Table 5.14. Number of instructional days and hours in the school year, by state: 2018. Retrieved from: https://nces.ed.gov/programs/statereform/tab5_14.asp.
- U.S. Department of Education National Center for Education Statistics (NCES). (2016). Common Core of Data (CCD), "National Public Education Financial Survey (State Fiscal)", 2016-17 v.1a; "Public Elementary/Secondary School Universe Survey", 2017-18 v.1a; "State Nonfiscal Public Elementary/Secondary Education Survey", 2016-17 v.1a, 2017-18 v.1a, 2018-19 v.1a. Retrieved from: https://nces.ed.gov/ccd/elsi/tableGenerator.aspx?savedTableID=126809.

Public Signage

GSI has the potential to contribute to increased environmentally responsible behaviors in three ways:

(1) by providing information about the connection between individual choices/actions and water pollution;

(2) by providing social signals that highlight responsible behavior; and

(3) by providing opportunities to engage directly in environmentally responsible behavior (U.S. Environmental Protection Agency, 2017).

One method to provide information to individuals is via public signage, which can positively affect community perceptions of the environment, community education with the space and overall improvements in the quality of life of surrounding residents (Thompson et al., 2013; U.S. Environmental Protection Agency, 2017). Autocase investigated the potential community benefit of installing BMP signage but was not able to monetize this impact due to inherent limitations in the literature.

References

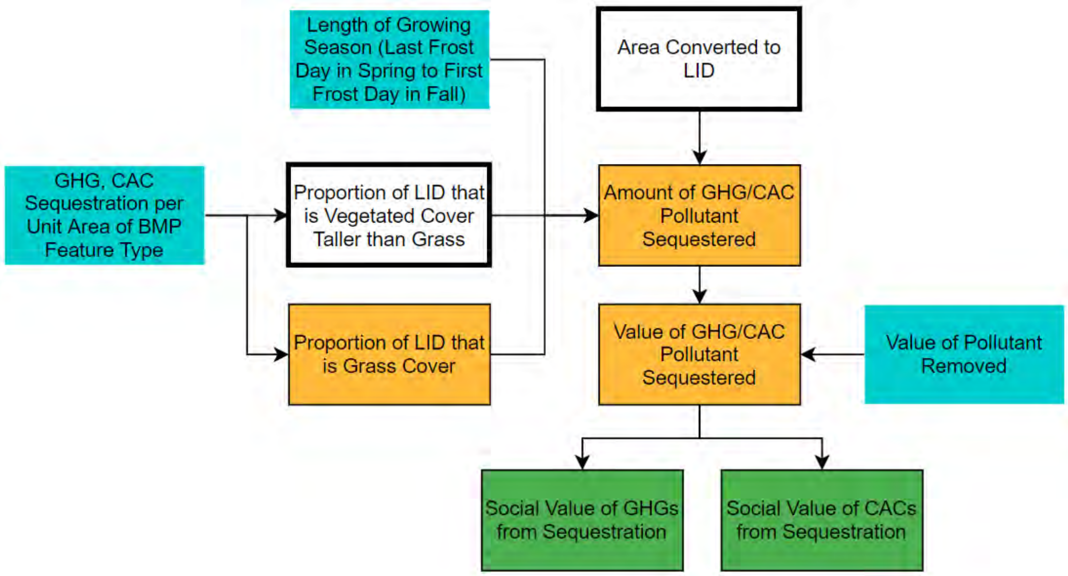
- Thompson, C. W., Roe, J., & Aspinall, P. (2013). Woodland improvements in deprived urban communities: what impact do they have on people's activities and quality of life?. Landscape and urban planning, 118, 79-89. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0169204613000224.
- U.S. Environmental Protection Agency. (2017). Expanding the benefits of Seattle's Green Stormwater infrastructure. Retrieved from: https://www.epa.gov/green-infrastructure/expanding-benefits-seattles-green-stormwater-infrastructure

Environmental Impacts

Carbon and Air Pollution Sequestration

Newly planted trees, shrubs, grasses, and plants can sequester carbon from the atmosphere, reducing the impacts of climate change. Additionally, growing trees, shrubs, grasses, and plants can act as 'carbon sinks,' absorbing carbon dioxide from the air and incorporating it into their stems or trunks, branches, and roots, as well as into the soil. While landscaping and maintenance activities result in greenhouse gas (GHG) emissions (referred to as the "lawnmower effect"), these activities are more than offset by the sequestration potential of BMPs. Criteria Air Contaminants (CACs) are air pollutants that are also emitted by fossil fuel combustion, which affect the health of people immediately in their vicinity. CACs are removed from the air by trees and shrubs. As the trees on site mature throughout the life of the project their canopies grow and capture air pollutants at an increasing rate.

Sequestration rates for both Carbon Dioxide (CO_2) and CACs are taken from literature. These studies include Leibig et al. (2008); Selhorst & Rattan (2013); Whittinghill et al. (2014); Qian et al. (2010); Zirkle et al. (2011); Gopalakrishnana et al. (2018); Nowak et al., (2013); and Yang et al. (2008). This makes it possible to estimate the metric tonnes of pollutants sequestered by the vegetation growing in the BMP being implemented. The existing vegetation cover of sites that are converted to BMPs is assumed to be low-height manicured lawn. BMPs that include vegetation - such as bioretention basins, and bioswales - are assumed to be medium height vegetation such as forbs and sedges. This helps to account for the differences in sequestration rates between different vegetation types. The metric tonnes of each pollutant are then multiplied by the social cost of each pollutant to determine the value of the change in pollution. The social costs of each pollutant are taken from literature as well as government documents. These studies include research conducted by EASIUR (2015); U.S. Department of Transportation (2017); Transportation Research Board (2002); Victoria Transport Policy Institute (2007); Muller and Mendelsohn (2007); Sawyer et al. (2007); IWG (2016); Rabl and Spadaro (2000); and Wang et al. (1994).



References

- The Estimating Air pollution Social Impact Using Regression (EASIUR) model: Marginal Social Costs of Emissions in the United States. (2015). Retrieved from: https://barney.ce.cmu.edu/~jinhyok/easiur/
- Gopalakrishnan, V., Hirabayashi, S., Ziv, G., & Bakshi, B. R. (2018). Air quality and human health impacts of grasslands and shrublands in the United States. *Atmospheric Environment*, 182, 193-199. Retrieved from: http://eprints.whiterose.ac.uk/129319/14/GopalakrishnanHirabayashiZivBakshi_Main_20180130_v2.pdf.
- Interagency Working Group (IWG) on the Social Cost of Carbon (2016). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866". Retrieved from: https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf
- Liebig, M. A., Schmer, M. R., Vogel, K. P., & Mitchell, R. B. (2008). Soil carbon storage by switchgrass grown for bioenergy. Bioenergy Research, 1(3), 215-222. Retrieved from: https://link.springer.com/article/10.1007/s12155-008-9019-5.
- Muller, N. Z., & Mendelsohn, R. (2007). Measuring the damages of air pollution in the United States. Journal of Environmental Economics and Management, 54(1), 1-14. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0095069607000095.
- Nowak, D. J., Hirabayashi, S., Bodine, A., & Hoehn, R. (2013). Modeled PM2. 5 removal by trees in ten US cities and associated health effects. Environmental pollution, 178, 395-402. Retrieved from: https://www.fs.usda.gov/treesearch/pubs/download/43676.pdf.

- Qian, Y., Follett, R. F., & Kimble, J. M. (2010). Soil organic carbon input from urban turfgrasses. Soil Science Society of America Journal, 74(2), 366-371. Retrieved from: https://pubag.nal.usda.gov/download/41350/PDF.
- Rabl, A., & Spadaro, J. V. (2000). Public health impact of air pollution and implications for the energy system. Annual review of Energy and the Environment, 25(1), 601-627. Retrieved from: https://www.annualreviews.org/doi/full/10.1146/annurev.energy.25.1.601.
- Sawyer, D., Stiebert, S., & Welburn, C. (2007). Evaluation of total cost of air pollution due to transportation in Canada. Transport Canada, Ottawa, ON, Canada. Retrieved from: http://www.bv.transports.gouv.qc.ca/mono/1022480.pdf.
- Selhorst, A., & Lal, R. (2013). Net carbon sequestration potential and emissions in home lawn turfgrasses of the United States. Environmental management, 51(1), 198-208. Retrieved from: https://link.springer.com/article/10.1007/s00267-012-9967-6.
- Transportation Research Board (TRB). (2002). Transit Cooperative Research Program (TCRP) Report 78: Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners. Retrieved from: http://www.trb.org/Publications/Blurbs/153766.aspx.
- U.S. Department of Transportation. (2017). Benefit Cost Analysis Guidance for Discretionary Grant Programs. Retrieved from: https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2017_2.pdf.
- U.S. Environmental Protection Agency. (2012). Regulatory Impact Analysis: Final New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry. Retrieved from: https://www.epa.gov/sites/production/files/2020-07/documents/oilgas_ria_final-neshap-amendments_2012-04.pdf.
- Victoria Transport Policy Institute. (2007). Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications. Chapter 5.10 - Air Pollution. Retrieved from: http://www.vtpi.org/tca/tca0510.pdf.
- Wang, M. Q., Santini, D. J., & Warinner, S. A. (1994). Methods of valuing air pollution and estimated monetary values of air pollutants in various US regions (No. ANL/ESD-26). Argonne National Lab., IL (United States). Center for Transportation Research. Retrieved from: https://www.osti.gov/servlets/purl/10114725-f7ktvT/webviewable.
- Whittinghill, L. J., Rowe, D. B., Schutzki, R., & Cregg, B. M. (2014). Quantifying carbon sequestration of various green roof and ornamental landscape systems. Landscape and Urban Planning, 123, 41-48. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0169204613002296.
- Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. Atmospheric environment, 42(31), 7266-7273. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S1352231008006262.

- Zirkle, G., Lal, R., & Augustin, B. (2011). Modeling carbon sequestration in home lawns. HortScience, 46(5), 808-814. Retrieved from: https://journals.ashs.org/hortsci/view/journals/hortsci/46/5/article-p808.xml.

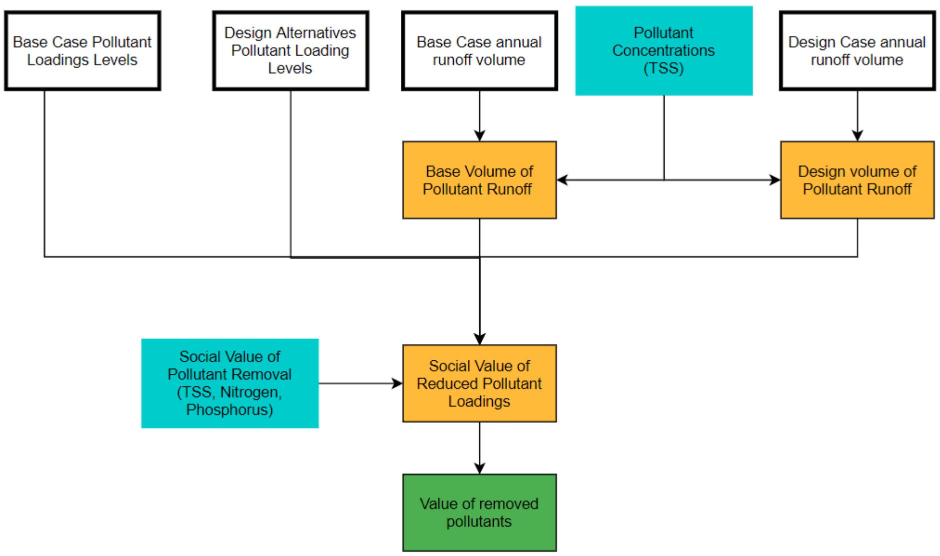
Water Quality - Pollutant Loading Reduction

Capturing stormwater and runoff before it enters surface waters also captures pollutants. By passively removing these pollutants through improved vegetated land cover, environmental damages are avoided. Autocase has valued the avoided damages from capturing nitrogen, phosphorus, and total suspended solids (TSS). In order to achieve this the Autocase team underwent an extensive literature review, compiling the most defensible sources available from academic journals, and government reports. It was determined that the state of the literature limits the number of different monetized damages that can be applied to the targeted pollutants. The values that follow represent the best available figures the Autocase team was able to source.

The environmental value for removing each pollutant is different as the environmental damages for releasing an additional unit of pollution differs depending on the type of undesirable loading released in waterways. Nitrogen is valued using the willingness to pay (WTP) of society to reduce the ecosystem impacts derived from nitrogen pollution emitted into waterways. WTP estimates represent a more holistic method in capturing the true value of reducing nitrogen pollutants, as compared to using an avoided cost of water treatment that reflects only the financial benefit, but does not take into consideration the associated environmental externalities.The value Autocase uses in this analysis to monetize reductions in nitrogen loadings is specific to pollution emitted to surface water sources, reflecting the marginal benefits of reducing eutrophication and impacts to biodiversity (Van Grinsven et al., 2013). This value was also used by the University of Virginia and University of New Hampshire to evaluate the institutional cost of Nitrogen runoff from their facilities (Compton et al., 2017). The value from literature for total Nitrogen is also in alignment with estimates found through integrated assessment modelling (as used to calculate the Social Cost of Carbon) to determine the Social Cost of Nitrogen (Keeler et al., 2016). The limitations of using the surface water valuation method from the Van Grinsven study is that it does not include human health impacts, which are only applied to nitrogen pollution emitted to groundwater sources that directly affect drinking water quality.

The value of phosphorus is based on the monetized benefits of increased property values for waterfront properties, improved recreational opportunities, and avoided costs of cleanup and management. This value was estimated by the Wisconsin Department of Natural Resources, where they found the amount of phosphorus reduced using regulatory measures, and divided by the total estimated benefits, to find the per pound value of reductions in phosphorus (WDNR, 2012).

The value of TSS is a shadow price determined from the water recycling process. A study used data collected from wastewater treatment plants to determine how much people were willing to pay for treated water quality improvements. They used a production function that had the production of various pollutants as a constraint for the creation of potable recycled water. The shadow price reflects how much society is willing to pay to get a unit of clean water by removing a kilogram of TSS (Hernández-Sancho, Molinos-Senante, et al., 2010).



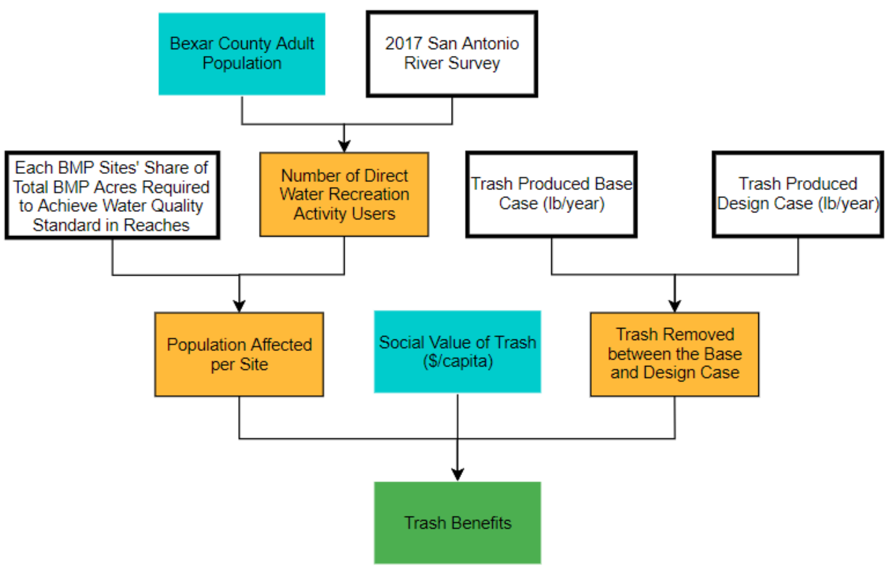
References

- Water pollutant loading inputs were provided by SARA, except for Total Suspended Solids (which were estimated by Autocase).
- Compton, J. E., Leach, A. M., Castner, E. A., & Galloway, J. N. (2017). Assessing the social and environmental costs of institution nitrogen footprints. Sustainability: The Journal of Record, 10(2), 114-122. Retrieved from: https://www.liebertpub.com/doi/pdf/10.1089/sus.2017.29099.jec.
- Hernández-Sancho, F., Molinos-Senante, M., & Sala-Garrido, R. (2010). Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain. Science of the total environment, 408(4), 953-957. Retrieved from: https://www.researchgate.net/profile/Ramon_Sala-Garrido/publication/226890917_Environmental_Benefits_of_Wastewater_Treatment_An_Economic_Valuation/links/5ab75edd0f7e9b68ef5030b2/Environmental-Benefits-of-Wastewater-Treatment-An-Economic-Valuation.pdf.
- Keeler, B. L., Gourevitch, J. D., Polasky, S., Isbell, F., Tessum, C. W., Hill, J. D., & Marshall, J. D. (2016). The social costs of nitrogen. Science Advances, 2(10), e1600219. Retrieved from: https://advances.sciencemag.org/content/advances/2/10/e1600219.full.pdf.
- Van Grinsven, H. J., Holland, M., Jacobsen, B. H., Klimont, Z., Sutton, M. A., & Jaap Willems, W. (2013). Costs and benefits of nitrogen for Europe and implications for mitigation. Environmental science & technology, 47(8), 3571-3579. Retrieved from:

http://www.iai.int/admin/site/sites/default/files/uploads/Van-Grinsven-et-al-2013-es303804g.pdf.
- The Wisconsin Department of Natural Resources (WDNR). (2012). Phosphorus Reduction in Wisconsin Water Bodies: A Economic Impact Analysis. Retrieved from: https://dnr.wi.gov/topic/SurfaceWater/documents/PhosphorusReductionEIA.pdf.

Trash

Structural and non-structural BMPs can be used to reduce the amount of trash loaded into streams subsequently carried to new areas. Compared to managed turf land covers, BMP installations can more effectively trap trash, thus reducing the amount that flows downstream affecting direct water users. The change in the amount of trash from the implementation of BMPs is taken from estimates provided by SARA GSI. This change in the amount of trash is valued using the social cost of trash (Stickel et al., 2013) as well as the population who would be impacted by the trash at each site (US Census Bureau, 2019; SARA, 2017).



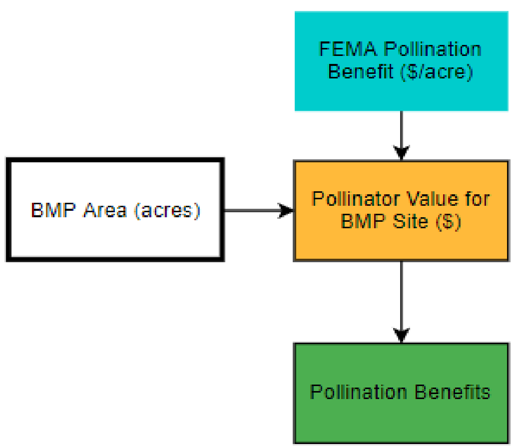
References

- Estimates of trash produced in the base and design case are provided by SARA.
- San Antonio River Authority (SARA). (2017). 2017 San Antonio River Survey. Provided via personal communications (emails) with SARA.
- Stickel, B. H., Jahn, A., & Kier, B. (2013). Waste in our water: The Annual Cost to California Communities of Reducing Litter That Pollutes our waterways. Kier Associates: San Rafael, CA. Retrieved from: https://www.nrdc.org/sites/default/files/oce_13082701a.pdf.
- U.S. Census Bureau. (2019). Quick Facts, Bexar County, Texas. Retrieved from: https://www.census.gov/quickfacts/fact/table/bexarcountytexas/PST045219.

Pollination

Pollination is a service provided by ecosystems when habitat is provided to pollinator species. The determination of the value of specific ecosystem services (such as pollination) provided by certain green infrastructure can be valued using the area of that infrastructure, and the per acre value to the ecosystem service, which is estimated by the Federal Emergency Management Agency (FEMA).

Pollinator benefits are expected to accrue to the environment by changing the management of the turf in these GSI sites and allowing the vegetation to grow longer and return to native land covers. Generally, pollination potential depends on how the project site is managed currently. Actively managing the landscape by mowing the grass low and applying a broadleaf herbicide are two of the common practices that are harmful to pollinator species. Alternatively, planting native/pollinator plants would provide more flowering plants for food and vegetative cover for pollinator habitat. Additional benefits to pollinators are expected to accrue if the native ground cover is allowed to fill in, eliminating the need for herbicide applications. Moreover, it is recommended that turf landscaping practices shift to unmanaged to enable more native land covers and limit herbicide use in open spaces.



References

- BMP area breakdowns were provided by SARA.
- Federal Emergency Management Agency (FEMA). (2013). Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs. Retrieved from: https://www.fema.gov/media-library-data/20130726-1920-25045-2892/environmental_benefits_calculator_v2.pdf.

Detailed Results Tables & Charts

Table 1. Results Summary of All Project Sites 1-8 | Net Present Value Over 50 Years Discounted at 3%

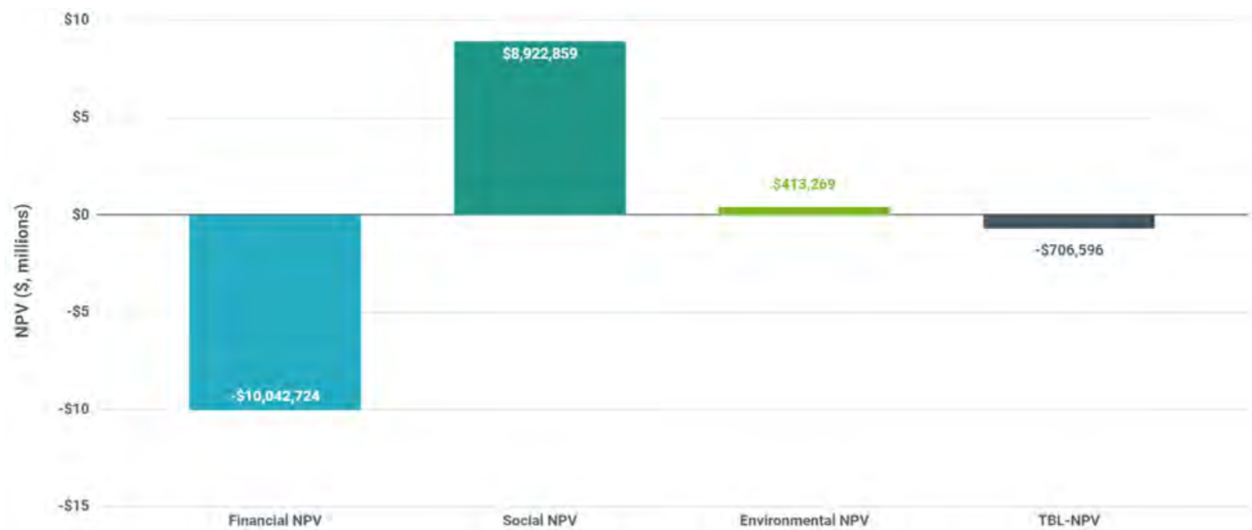
Impact		Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
Financial	Capital Expenditures	-$318,400	-$263,700	-$754,800	-$132,700	-$155,000	-$263,800	-$181,900	-$2,481,000
	Operations & Maintenance	-$450,800	-$543,600	-$1,498,000	-$161,900	-$194,300	-$185,400	-$240,600	-$811,100
	Replacement Costs	-$223,379	-$190,590	-$530,795	-$57,342	-$68,835	-$68,624	-$89,051	-$284,379
	Residual Value	$21,100	$12,700	$35,500	$3,830	$4,600	$4,590	$5,950	$19,000
Social	Flood Risk	$850	$400	$1,156	$72	$221	$93	$221	$647
	Education	$30,915	$0	$30,915	$30,915	$30,915	$0	$0	$0
	Urban Heat Island	$6,700	$3,080	$8,610	$930	$1,120	$1,110	$1,440	$4,620
	Open Space - Recreation	$7,410	$3,250	$1,190	$190	$1,200	$0	$0	$0
	Water Quality - Induced Recreation	$2,126,544	$1,668,031	$2,731,634	$295,244	$354,365	$353,296	$458,359	$767,218
Environmental	Air Pollution from Sequestration	$880	$400	$1,130	$120	$150	$150	$190	$600
	Carbon Emissions from Sequestration	$71,100	$32,700	$91,300	$9,860	$11,800	$11,800	$15,300	$49,000
	Trash	$17,209	$7,846	$22,017	$2,278	$2,784	$2,784	$3,797	$11,895
	Water Quality - Pollutant Loading Reduction	$4,298	$4,412	$11,507	$934	$1,027	$1,363	$982	$3,194
	Pollination	$4,480	$2,062	$5,754	$622	$747	$744	$966	$3,087
Financial NPV		-$971,479	-$985,190	-$2,748,095	-$348,112	-$413,535	-$513,234	-$505,601	-$3,557,479
Social NPV		$2,172,419	$1,674,761	$2,773,505	$327,351	$387,821	$354,499	$460,020	$772,485
Environmental NPV		$97,967	$47,420	$131,708	$13,814	$16,508	$16,841	$21,235	$67,776
Triple Bottom Line NPV		$1,298,907	$736,991	$157,118	-$6,947	-$9,206	-$141,895	-$24,346	-$2,717,218

Autocase Economic Advisory

Table 2. Results of All Project Sites | Net Present Value Over 50 Years Discounted at 3%

Impact		All Sites (1 - 8)
Financial	Capital Expenditures	-$4,551,300
	Operations & Maintenance	-$4,085,700
	Replacement Costs	-$1,512,994
	Residual Value	$107,270
Social	Flood Risk	$3,658
	Education	$123,660
	Urban Heat Island	$27,610
	Open Space - Recreation	$13,240
	Water Quality - Induced Recreation	$8,754,691
Environmental	Air Pollution from Sequestration	$3,620
	Carbon Emissions from Sequestration	$292,860
	Trash	$70,610
	Water Quality - Pollutant Loading Reduction	$27,717
	Pollination	$18,462
Financial NPV		-$10,042,724
Social NPV		$8,922,859
Environmental NPV		$413,269
Triple Bottom Line NPV		**-$706,596**

Figure 1. Comparison of the Expected TBL-NPV of Financial, Social, and Environmental Results For All Project Sites (1 - 8) | Net Present Value Over 50 Years Discounted at 3%



Appendix

Inputs from SARA

Autocase BMP Mapping

SARA BMP Nomenclature	Autocase BMP Classification
Bioretention	Bioretention / Rain Garden
Extended Detention Basin	Dry Detention Pond
Bioswale	Vegetated Buffer Strip / Swale

Site BMP Area

Site 1 (Subbasin 70)	Unit	Area
Base Case	Acres	0.5971
Managed Turf	Acres	0.5971
Design Case	Acres	0.5971
Extended Detention Basin	Acres	0.5175
Bioswale	Acres	0.0796

Site 2 (Subbasin 150)	Unit	Area
Base Case	Acres	0.2748
Managed Turf	Acres	0.2748
Design Case	Acres	0.2748
Bioretention	Acres	0.2748

Site 3 (Subbasin 260)	Unit	Area
Base Case	Acres	0.767
Managed Turf	Acres	0.767
Design Case	Acres	0.767
Bioretention	Acres	0.767

Site 4 (Subbasin 270)	Unit	Area
Base Case	Acres	0.0829
Managed Turf	Acres	0.0829
Design Case	Acres	0.0829
Bioretention	Acres	0.0829

Site 5 (Subbasin 310)	Unit	Area
Base Case	Acres	0.0995
Managed Turf	Acres	0.0995
Design Case	Acres	0.0995
Bioretention	Acres	0.0864
Bioswale	Acres	0.0131

Site 6 (Subbasin 330)	Unit	Area
Base Case	Acres	0.0992
Managed Turf	Acres	0.0992
Design Case	Acres	0.0992
Bioretention	Acres	0.0992

Site 7 (Subbasin 420)	Unit	Area
Base Case	Acres	0.1287
Managed Turf	Acres	0.1287
Design Case	Acres	0.1287
Bioretention	Acres	0.1287

Site 8 (Subbasin 560)	Unit	Area
Base Case	Acres	0.4114
Managed Turf	Acres	0.4114
Design Case	Acres	0.4114
Bioswale	Acres	0.4114

BMP Pollutant Loading Reduction Estimates (per Year)

Pollutant[1]	Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
E. coli Bacteria (#10^6 org/year)	3,169,665	2,469,138	5,224,657	364,237	695,394	748,023	800,312	954,169
NO3N = Nitrate-Nitrogen (lb/year)	3.1887	7.8064	20.1489	1.5600	1.7740	2.1174	1.6844	4.4020
NH4N = Ammonia-Nitrogen (lb/year)	2.1390	5.1376	13.2526	1.0146	1.1534	1.3446	1.0419	2.5342
Organic nitrogen (lb/year)	0.9275	6.2649	16.9378	1.6029	1.6298	2.4369	1.6969	6.1071
Total Phosphorus (lb/year)	2.8394	3.2859	8.1999	0.5291	0.6143	0.7896	0.5569	1.9171
ORTHOP = Orthophosphorus (lb/year)	1.1319	1.3128	3.2801	0.2105	0.2483	0.3143	0.2218	0.7696
TSS (tons/year)	**14.8773**	**0.7753**	**2.1355**	**0.2151**	**0.2399**	**0.5165**	**0.1929**	**1.9949**
Outflow Volume (OVOL) (acre feet/year)	0.2493	0.9476	2.6100	0.2629	0.2932	0.6313	0.2358	2.4382

[1] **Bolded line items indicate pollutant loadings estimated by Autocase.**

Financial Costs of Land Covers

Cost	Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
Upfront Capital Costs	$337,789.38	$279,787.20	$800,762.73	$140,763.44	$164,476.73	$279,873.79	$192,952.55	$2,631,888.00
Annual O&M Costs	$19,686.50	$22,920.00	$63,841.75	$6,898.92	$8,279.85	$8,253.11	$10,709.37	$34,196.64
Replacement Costs								
6-10 Years	$24,000.00	$35,280.00	$98,269.50	$10,619.28	$12,744.90	$12,703.74	$16,484.58	$52,637.76
20 Years	$202,111.25	$122,040.00	$339,932.25	$36,734.04	$44,086.95	$43,944.57	$57,023.19	$182,083.68
Base Case Annual O&M Cost Estimates								
Managed Turf ($ / square foot)	$0.03	$0.01	$0.03	$0.03	$0.03	$0.11	$0.11	$0.01

References

- Base Case Annual O&M Cost Estimates for Sites 1, 2, 3, 4, 5, and 8 were provided by SARA. Due to receiving no data from SARA on O&M estimates for Site 6 and 7, Autocase used an average of the highest SARA estimate ($0.03 / sq ft) and Autocase's literature reviewed-value of O&M for managed turf ($0.19 / sq ft) to determine a value of $0.11 / sq ft for Site 6 and 7 base case managed turf O&M costs.

- Cheng, H., Hu, Y., & Reinhard, M. (2014). Environmental and health impacts of artificial turf: a review. Environmental science & technology, 48(4), 2114-2129. Retrieved from: https://core.ac.uk/download/pdf/71730025.pdf.
- Hall, C. R., Sorochan, J. C., & Samples, T. (2005). Costs of managing a bermudagrass football field in Tennessee. Univ. Tenn. Ag. Ext. Factsheet, 651. Retrieved from: https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1019&context=utk_agexcomhort.
- San Antonio River Authority (SARA). (2019). San Antonio River Basin Low Impact Development Technical Design Guidance Manual. Second Edition. Retrieved from: https://www.sariverauthority.org/sites/default/files/2019-08/SARB%20LID%20Technical%20Design%20Manual%202nd%20Edition.pdf.
- Uhlman, B., Diwan, M., Dobson, M., Sferrazza, R., & Songer, P. (2010). Synthetic Turf, Eco-Efficiency Analysis Final Report. Florem park NJ, BASF Corporation. NSF Protocol P, 352. Retrieved from: https://d2evkimvhatqav.cloudfront.net/documents/Synthetic_Turf_EEA_Study_Verification_Final.pdf.

- U.S. Environmental Protection Agency. (1995). Appendix 8. Examples of Natural Landscaping Installation and Maintenance Cost. Retrieved from: https://archive.epa.gov/greenacres/web/pdf/appendix8.pdf.
- U.S. Environmental Protection Agency. (2019). July 2019 Report: Tire Crumb Rubber Characterization: Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan - Final Report Part 1 - Volume 2. Retrieved from: https://www.epa.gov/sites/production/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_2.pdf.

Inputs from Autocase

General Inputs

Input	Expected Value
Project name	SARA GSI Master Pan
State	TX
City	San Antonio
Zip Code	78247
Project Start Date	08/2022
Construction Period (years)	1
Operations Period (years)	50
Discount Rate	3%

Project Location Characteristics

Input	Units	Average
Length of growing season (replaces non-frost days)	#	299
Population of City (2019)	#	1,547,253
Housing Density	Houses / sq mile	180.30
Area of the City (2010)	sq mile	460.93
City Area in Floodplain	%	5.0
Property Value (2019)	$	164,458

References

- U.S. Census Bureau (2020). Quick Facts. Scan Antonio City, Texas. Retrieved from: https://www.census.gov/quickfacts/fact/table/sanantoniocitytexas/POP060210.
- Weather Spark (2020). Average Weather in San Antonio. Retrieved from: https://weatherspark.com/y/7137/Average-Weather-in-San-Antonio-Texas-United-States-Year-Round.
- Zillow (2020). Zillow Home Value Index (ZHVI). Housing Data. Retrieved from: https://www.zillow.com/research/data/.

Advanced Inputs

Input	Unit	Expected Value[2]
Social Cost of NO_x	$ / metric tonnes	10,692.29
Social Cost of SO_2	$ / metric tonnes	37,617.47
Social Cost of $PM_{2.5}$	$ / metric tonnes	219,262.52
Social Cost of VOC	$ / metric tonnes	2,262.60
Social Cost of Carbon (SCC)	$ / metric tonnes	51.94
SCC growth rate (2010-2020)	% / year	3.55
SCC growth rate (2020-2030)	% / year	1.90
SCC growth rate (2030-2040)	% / year	2.00
SCC growth rate (2040+)	% / year	1.50
Social Cost of TSS	$ / kg	0.01
Social Cost of Total Nitrogen	$ / kg	17.71
Social Cost of Total Phosphorus	$ / kg	12.05
Social Cost of Trash	$ / person / year	12.49
Value of Statistical Life	$ / person	9,503,528.51

References

- The Estimating Air pollution Social Impact Using Regression (EASIUR) model: Marginal Social Costs of Emissions in the United States. (2015). Retrieved from: https://barney.ce.cmu.edu/~jinhyok/easiur/.
- Hernández-Sancho, F., Molinos-Senante, M., & Sala-Garrido, R. (2010). Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain. Science of the total environment, 408(4), 953-957. Retrieved from: https://www.researchgate.net/profile/Ramon_Sala-Garrido/publication/226890917_Environmental_Benefits_of_Wastewater_Treatment_An_Economic_Valuation/links/5ab75edd0f7e9b68ef5030b2/Environmental-Benefits-of-Wastewater-Treatment-An-Economic-Valuation.pdf.

[2] All dollar values are in 2020 U.S. Dollars (USD).

- Interagency Working Group (IWG) on the Social Cost of Carbon (2016). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866". Retrieved from: https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf
- Muller, N. Z., & Mendelsohn, R. (2007). Measuring the damages of air pollution in the United States. Journal of Environmental Economics and Management, 54(1), 1-14. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0095069607000095.
- Rabl, A., & Spadaro, J. V. (2000). Public health impact of air pollution and implications for the energy system. Annual review of Energy and the Environment, 25(1), 601-627. Retrieved from: https://www.annualreviews.org/doi/full/10.1146/annurev.energy.25.1.601.
- Sawyer, D., Stiebert, S., & Welburn, C. (2007). Evaluation of total cost of air pollution due to transportation in Canada. Transport Canada, Ottawa, ON, Canada. Retrieved from: http://www.bv.transports.gouv.qc.ca/mono/1022480.pdf.
- Stickel, B. H., Jahn, A., & Kier, B. (2013). Waste in our water: The Annual Cost to California Communities of Reducing Litter That Pollutes our waterways. Kier Associates: San Rafael, CA. Retrieved from: https://www.nrdc.org/sites/default/files/oce_13082701a.pdf.
- Transportation Research Board (TRB). (2002). Transit Cooperative Research Program (TCRP) Report 78: Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners. Retrieved from: http://www.trb.org/Publications/Blurbs/153766.aspx.
- U.S. Department of Transportation. (2017). Benefit Cost Analysis Guidance for Discretionary Grant Programs. Retrieved from: https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2017_2.pdf.
- U.S. Environmental Protection Agency. (2010). Guidelines for preparing economic analyses. Retrieved from: https://www.epa.gov/sites/production/files/2017-08/documents/ee-0568-50.pdf.
- U.S. Environmental Protection Agency. (2012). Regulatory Impact Analysis: Final New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry. Retrieved from: https://www.epa.gov/sites/production/files/2020-07/documents/oilgas_ria_final-neshap-amendments_2012-04.pdf.
- Van Grinsven, H. J., Holland, M., Jacobsen, B. H., Klimont, Z., Sutton, M. A., & Jaap Willems, W. (2013). Costs and benefits of nitrogen for Europe and implications for mitigation. Environmental science & technology, 47(8), 3571-3579. Retrieved from: http://www.iai.int/admin/site/sites/default/files/uploads/Van-Grinsven-et-al-2013-es303804g.pdf.

- Victoria Transport Policy Institute. (2007). Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications. Chapter 5.10 - Air Pollution. Retrieved from: http://www.vtpi.org/tca/tca0510.pdf.
- Wang, M. Q., Santini, D. J., & Warinner, S. A. (1994). Methods of valuing air pollution and estimated monetary values of air pollutants in various US regions (No. ANL/ESD-26). Argonne National Lab., IL (United States). Center for Transportation Research. Retrieved from: https://www.osti.gov/servlets/purl/10114725-f7ktvT/webviewable.
- The Wisconsin Department of Natural Resources (WDNR). (2012). Phosphorus Reduction in Wisconsin Water Bodies: A Economic Impact Analysis. Retrieved from: https://dnr.wi.gov/topic/SurfaceWater/documents/PhosphorusReductionEIA.pdf.

Subtask 4.3 - Stakeholder Engagement Report

This report is a record of the stakeholder engagement and feedback San Antonio River Authority (River Authority) received on the eight sites modeled as part of the work to create the Green Stormwater Infrastructure (GSI) Master Plan. It includes the stakeholder engagement process, stakeholder groups, stakeholder activities, stakeholder input on potential GSI implementation, and a summary record of the community workshops.

In addition, any project information and educational materials developed for the project and posted to the website is included. Also included are social media announcements and promotion of events and educational materials. The community workshops documentation includes announcements, agendas, presentation materials, and sign-in sheets.

The first step was to identify potential stakeholders for each priority subbasin. These included local governments, property owners, neighborhood associations, and non-profits who would have an interest in the potential implementation sites. Some stakeholders were engaged during the project application process, prior to the project being funded. Those stakeholders that provided a letter of support for the project application are identified below.

Stakeholder groups identified within the eight priority subbasins:

- The City of San Antonio
    - Office of Sustainability (provided letter of support)
    - Planning & Community Development
    - Public Works Department (was Transportation and Capital Improvement)
        - provided letter of support for the grant project application
    - Office of Equity
    - Parks and Recreation Department
- Bexar Regional Watershed Management (BRWM) – Management Committee
    - Office of Sustainability Department
    - Planning & Community Development
    - Public Works Department
    - Parks and Recreation Department
- BRWM – Watershed Technical Committee (WTC)
    - Public Works Department
    - San Antonio Water Systems
        - Bexar County Stormwater Department (provided letter of support)
- Suburban Cities in priority areas
- Homeowners & Neighborhood Associations
- San Antonio Housing Authority (SAHA)
- SA 2030 District
- SA Climate Ready Plan
- SA Tomorrow Regional Centers
- Build San Antonio Green

The potential implementation sites were identified and presented to the stakeholders identified for the specific sites. Details on the site identification are outlined in the Dataset of Potential GSI Projects (Subtask 3.2). The River Authority presented this information to the following stakeholders: the BRWM

– Watershed Technical Committee (WTC), the San Antonio Housing Authority, and the City of San Antonio Parks Department.

Feedback from the stakeholder outreach is recapped below:

- The City of San Antonio Transportation & Capital Improvements Department (now Public Works) noted:
  - *No future projects were found near the proposed sites in the SA Watershed.*
  - *Find sites where these considerations are maximized:*
    - *Ease of constructability- sites where retrofitting for GSI works with the layout of the site.*
    - *Availability of infrastructure- sites with nearby infrastructure that can be tied into (channels, pipes, etc.).*
    - *Limit direct outfall into streets. This can exacerbate street maintenance issues.*
    - *Maintenance accessibility- select sites with sufficient access or where additional access can be obtained.*
- The San Antonio Water Systems noted site constraints on all potential implementation sites as part of the preliminary site selection. Sites were taken off the list based on their input, listed below:
  - *070-02 – SAWS Turtle Creek primary pump station. Between the water tanks, water wells, the large underground piping and the service pumps this site is unusable.*
  - *330-06 and 05 – COSA detention basin. The whole site is upstream detention for Woodlawn lake flooding.*
  - *330-05 – COSA park and detention basin.*
  - *330-02 – Concrete drainage ditch, has big power lines running in middle of it.*
  - *310-01 – SAWS Callaghan water tank – very small site, water tank occupies 75% of property.*
  - *310-02 - Large city owned park.*
  - *150-04 – Terrell Hills – Almost all of lot is covered with building. Drainage infrastructure takes up the rest and there is a large impervious drainage area into the site.*
  - *150-03 and 05 – Pocket parks… really it is just a green area, but it all sits higher than the surrounding roads. Has playground equipment on one of them and a neighborhood garden on the other.*
  - *150-02 there is a drainage on southside of property, but the football field takes up the rest of the green space.*
  - *150-01 – site is flat, mostly soccer fields at elementary school.*
  - *260-03 – houses one of the SW permitted outfall test sites. Please leave out.*
- The San Antonio Housing Authority expressed interest in implementing GSI on their properties.
- The City of San Antonio's Parks and Recreation Department has GSI outlined in their Master Plan and are interested in discussing the potential to implement GSI in the identified sites.

With that stakeholder feedback and additional River Authority staff input and site assessment by the Lockwood, Andrews & Newnam, Inc. (LAN) modeling team, one of the potential implementation sites was chosen to model in each of the eight subbasin. This process and outcome were documented in the Technical Memorandum for HSPF Modeling for BMP Performance Evaluation, Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP) Task 5. With the eight sites modeled with GSI BMPs, cost estimation, concept design and site scale drawings were performed on the sites.

The site GSI BMP modeling results, cost estimation, concept design and site scale drawings were presented at stakeholder workshops for the stakeholders/property owners of each site. Meeting notes, sign in sheet and outcomes are outlined below. The workshops were held virtually due to the COVID-19 pandemic. The property owners and stakeholder identified were outreached with the following email request.

I am reaching out to request feedback as part of the next phase of the Green Stormwater Infrastructure (GSI) Master Plan, an EPA/TCEQ 319 Grant. We are looking for feedback from property owner/stakeholders on the sites that were modeled with GSI best management practices for water quality improvements. I am looking to present the work done on [Brook Development Authority, City Public Works ROWs, City Parks and Recreation Department, and Terrell Heights Neighborhood Community Garden/Green Space, San Antonio Housing Authority] sites for feedback in a short virtual workshop. I have attached a brief presentation to give you a visual overview of the project and the sites. Please feel free to loop in others as you see fit.

Below is a summary of the grant project and outline of the virtual workshop.

The Upper SA River Watershed GSI Master Plan is an EPA/TCEQ Clean Water Act 319(h) Grant Project. The plan builds on recommendations made in the Upper SA River Watershed Protection Plan and Implementation Plan, Investments the River Authority has made in water quality models, and watershed master plan integration to develop a GSI Master Plan for the Upper SA River Watershed in Bexar County.

The River Authority is implementing this project to model select locations within targeted sub-watersheds to identify opportunities for implementing GSI and then to share outcomes with key stakeholders toward greater understanding of the opportunities, barriers, costs, etc. A priority is being given to space within public rights of way and/or on public lands. As I mentioned, the River Authority identified and modeled [four City parks, two Public ROWs, two SAHA Apts.] with GSI BMPs. I would like the opportunity to talk with you and other [City of San Antonio Public Works staff, Terrell Heights Community Members, City of San Antonio Parks and Recreations staff, Brooks Development Authority stakeholders, and San Antonio Housing Authority staff] whom you recommend, regarding the results and your thoughts about them.

Stakeholder Workshop Outline:

The purpose is to share the project with property owners and stakeholders to gather feedback and input on the work done to identify and model GSI/LID BMPs on public property as well as implementation potential.

- *Overview of the GSI Master Plan - EPA 319 Grant Project*
- *Review GSI opportunities on site(s)*
- *Provide an overview of the site's water quality modeling, triple bottom line analysis, and concept-level designs*
- *Gather feedback on GSI feasibility, funding, and barriers as well as priority of the two potential projects.*

Workshop 1: Terrell Heights Neighborhood Association (THNA) Board on Site 150, City of San Antonio Right-Of-Way (ROW).

A virtual meeting was held for the Terrell Heights Community on April 6, 2021. A presentation was made to the Terrell Heights Neighborhood Association Board. In attendance was the president and other members of the board. The meeting invitation and updated presentation that was shared with the group are attached in Appendix E. The presentation was updated to include the yard signs and other detailed GSI information the board requested to share with their neighborhood groups on NextDoor and Facebook. The presentation is attached in Appendix I.

The THNA Board and Community Garden lead requested signage to advertise the project to the community and gather feedback prior to a community meeting. The TNHA Board created a Survey and QR Code link to gather input on a set of questions I created for all stakeholders as well as a few of their own. The signage created for the ROW green space is shown in Appendix G.

The QR code in the signage is linked to the Terrell Heights Neighborhood Survey, pictured below. Survey participants were given access to the presentation as well as some additional questions and information provided by the THNA. The Terrell Heights Neighborhood Survey Image, Link, and Questions/Responses are in listed in the Appendix H.

The THNA Board and Community Gardening lead requested a follow up presentation to the community to share an overview of the project, discuss the feedback on the THNA Survey, and answer any questions. The invitation for the virtual meeting is pictured below. It was shared with the community in the form of a flyer, NextDoor App, and THNA Facebook post.

Workshop 2: City of San Antonio Public Works Department on Site 150 and Site 560.

A meeting was held on March 9, 2021 with Roberto Reyna, Capital Programs Manager, and staff from the Department of Public Works, and River Authority staff. The meeting invitation, agenda, and presentation are attached in Appendix I. Their input is summarized below.

The City of San Antonio's Public Works Department is interested in reviewing the ROW Terrell Heights community feedback, largely in support, as well as project details for potential implementation. Their goal is to align with the City's Water Quality Visioning Document and plan projects in the high priority subbasins, which this project is. In meeting with department director and managers to discuss opportunities they looked at the ROW opportunities relative to existing and future bond projects opportunities to add GSI BMPs.

Workshop 3: The Brooks Development Authority on Site 560.

A meeting was held on March 25, 2021, coordinated with Ana Gonzalez with the Brooks Development Authority, and attended by owners, members of the Brooks Development team, and their consultant, Pape-Dawson, and River Authority staff. A summary of their input is below. A list of participants and the presentation is in Appendix J.

The Brooks Development Authority stated that the Sydney Brooks and City-Base Landing site isn't an ideal candidate because it is a relatively new construction project. A separate meeting with the Brooks Development Authority, their consultants, and the landowner resulted in similar concerns with additional design and construction concerns due to it being in the center of the road. They are looking for opportunities similar to the three current San Antonio River Authority GSI/LID Rebate projects in Brooks.

Additional Workshops 4 & 5:

Additional Stakeholder Workshops/Meetings were held to ensure feedback was received from all site property owners and operators identified. They included the City of San Antonio's Parks and

Recreation Department and the San Antonio Housing Authority. Feedback from these two groups is recapped below.

Workshop 4: City of San Antonio Parks and Recreation Department on Sites 70, 310, 260, 270.

The City's Parks and Recreation Departments met with River Authority staff on March 31, 2021 to discuss the Park's sites; 70 - Windsor Park, 310 – Lee's Creek Park, 260 – Monterrey Park, 270 – Rosedale Park. COSA Parks expressed interested in implementing GSI on redevelopment and future projects. They looked for alignment with their priorities as well as current and future planned and bond projects. Meeting details are documented in Appendix K.

1. Site 70 – Windsor Park has a plan for retrofitting. The current plan is to return an old tennis court in disrepair to native vegetation. This is a great opportunity to turn it instead into a GSI feature like the extended detention basins and bioswales modeled in this neighborhood park.
2. Site 310 – Lee's Creek Park has had recent investment and use plans that may be an opportunity to work with the Public Works Department to fund the GSI with grant, bond, and/or other funding opportunities.
3. Site 260 – Monterrey Park, may be an opportunity to incorporate GSI with the trail head bond work being planned.
4. Site 270 – Rosedale Park currently has no upcoming work considered. When future work is planned GSI opportunities will be considered.

Workshop 5: San Antonio Housing Authority on Sites 330 and 420.

A meeting with the San Antonio Housing Authority on May 4, 2021 revealed that SAHA is interested in incorporating GSI BMPs in future projects if their private partners are also interested. They are willing to discuss retrofitting existing projects internally as funding is available. Meeting details are documented in Appendix L.

1. Site 330 – San Antonio Housing Authority's Pin Oak II Apartments will be discussed with their Asset and Property Management Departments. SAHA is interested in implementing GSI in future funded construction projects. Due to funding allocation processes it is easier for them to build GSI into design plans at the start of a project as opposed to a retrofit project.
2. Site 420 – San Antonio Housing Authority's Tampico Street Apartments is currently in construction and the real estate transaction is closed, so it is not possible to implement the proposed GSI BMP features at this time. It could be part of future retrofit conversations with asset and property management departments. SAHA is interested in implementing GSI in future development in coordination with their private partners and the River Authority.

Appendix A. Subtask 3.2 – Dataset of Potential GSI Projects

Desktop Analysis of Geospatial Data (Task 1- Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP))

The desktop analysis of geospatial data used a multi-criteria evaluation for site suitability process to identify the top five most suitable sites in each high priority subbasin. The evaluation was based on the following spatial datasets, also called geographic units (source provided in parenthesis):

- Bexar Land Use and Land Cover (Merrick)
- High priority subbasins: *GSI subbasins* (San Antonio River Authority, 2019h.)
- Upper San Antonio River Watershed Boundary (USGS)
- Soils (NRCS)
- Available Land (San Antonio River Authority, 2019h)
- Stream Centerlines (Federal Emergency Management Agency, FEMA)
- Flood risk *Damage Centers* (San Antonio River Authority, 2013)
- Storm drain inlets and drainage channels (City of San Antonio, COSA)
- Future bond projects (COSA)

Using ArcGIS Pro, version 2.2.1 (update version 2.5.1), the Available Land layer was overlaid with the other datasets. Areas with Available Land polygons greater than one acre belonging to public entities within the high priority subbasins were evaluated with the following criteria:

- Stream Centerlines (FEMA): located within 500 yards of a stream as defined by its centerline (preferred)
- Waterbodies (National Hydrography Dataset, NHD): located outside of waterbodies (required)
- Wetlands (National Wetlands Inventory, NWI): located outside of wetlands (required)
- Floodplains (FEMA): located outside of 1% annual chance floodplain (preferred)
- Flood risk Damage Centers (The River Authority): prioritized locations within flood risk damage centers (preferred)
- Open channels (COSA): potential green infrastructure opportunities, such as restoration areas (opportunity)
- Storm drain inlets (COSA): located within 500 yards of MS4 storm drain inlets (preferred)
- Future bond projects (COSA): located within future bond project area (preferred)
- Soils (NRCS): located on well-draining soils (hydrologic soil groups A and B) (preferred)
- Bexar Land Use and Land Cover (Merrick): located adjacent to a land use associated with high percentage of impervious cover including Commercial, Industrial, and Transportation (preferred)

Bullet points, above, are GIS Layers that can be found on the GSI Web Map, linked here: https://arcg.is/1ezmir. They are also provided in a geodatabase packet, attached, all except for the FEMA layer, that is hosted by FEMA.

For every subbasin, at least five sites were selected based on these criteria with an emphasis on the size of the land available (one acre or larger), the property owner, and proximity of grey infrastructure to a site. With the list of sites, a polygon layer was created by digitizing pervious features on the ground using Nearmap Imagery (sub two-inch resolution) as reference. The polygon layer included the following attribute information: Subbasin ID, sarbcode (sarbcode is the name of the field, San Antonio River Basin (SARB) code is a land use code used for modeling), impervious, description, area (sq. miles), area (acres), soil, notes, and owner information. A site ID was created using the subbasin ID number and a simple number sequence, e.g. 150_01, 150_02, 150_03, etc. The process of selecting sites was a manual effort requiring professional judgement. Simple layer overlays and map cartography techniques were used to differentiate layers from one another and to highlight a specific attribute, i.e. sarbcode or property owner.

The available land was digitized to obtain an accurate representation of the area in acres.

File Names:

- GSI_USAR_sub150_Site_Locations
- GSI_USAR_sub260_Site_Locations
- GSI_USAR_sub270_Site_Locations
- GSI_USAR_sub310_Site_Locations
- GSI_USAR_sub330_Site_Locations
- GSI_USAR_sub420_Site_Locations
- GSI_USAR_sub560_Site_Locations
- GSI_USAR_sub70_Site_Locations

In addition, the following attribute information was captured: Name, SubbasinID, SARANotes, LANComments, SiteID, Consider. The Name field was derived by either researching the property using Google Maps or referencing the latest Bexar County Appraisal district parcel layer, Bexar Parcels (BCAD, 2017h). The fields SARANotes and LANComments, were created to house land characteristic descriptions such as, area is adjacent to major roadway or inlet is present on site. The Consider field was created to denote sites that may not be feasible due to its ability to fit within the criteria listed above. This information will be used in the feasibility assessment, next steps, to help narrow down the site selections, to one site per subbasin.

File Name: Site_selections

The following images are snapshots of what that process looked like visually.

Figure 1. Subbasin 70 (black outline) with the available land (green) overlaid.

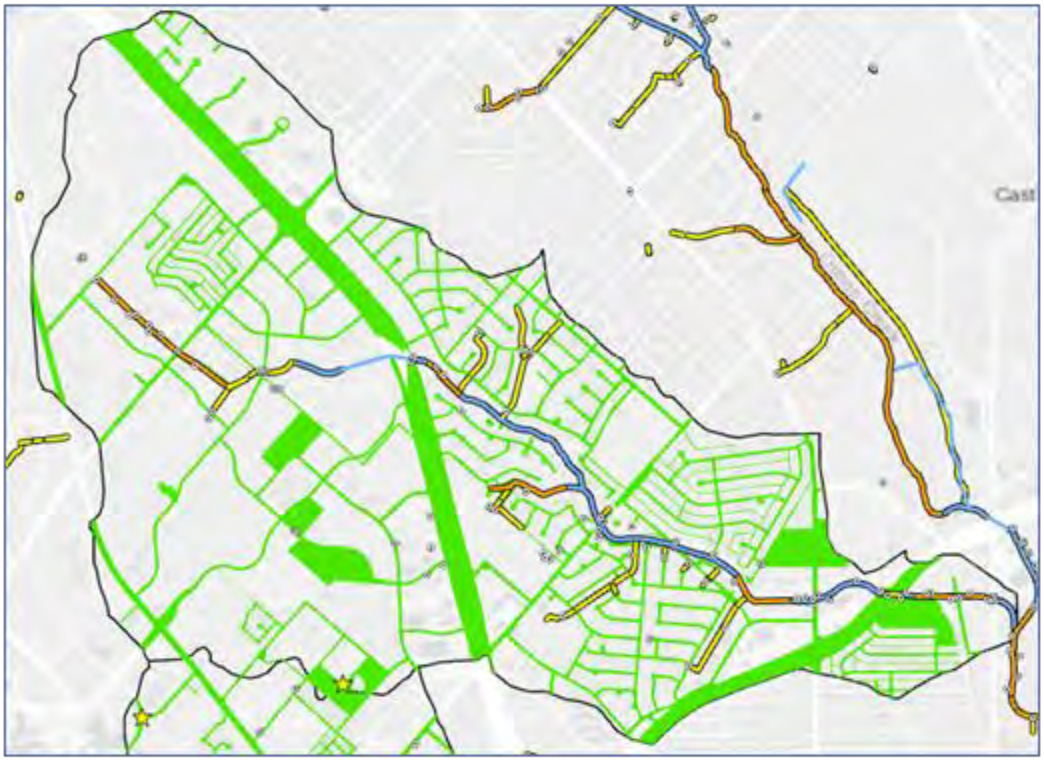


Figure 2. Subbasin 70 (black outline) with available land (green) coupled with layers from the SA River Authority's criteria.

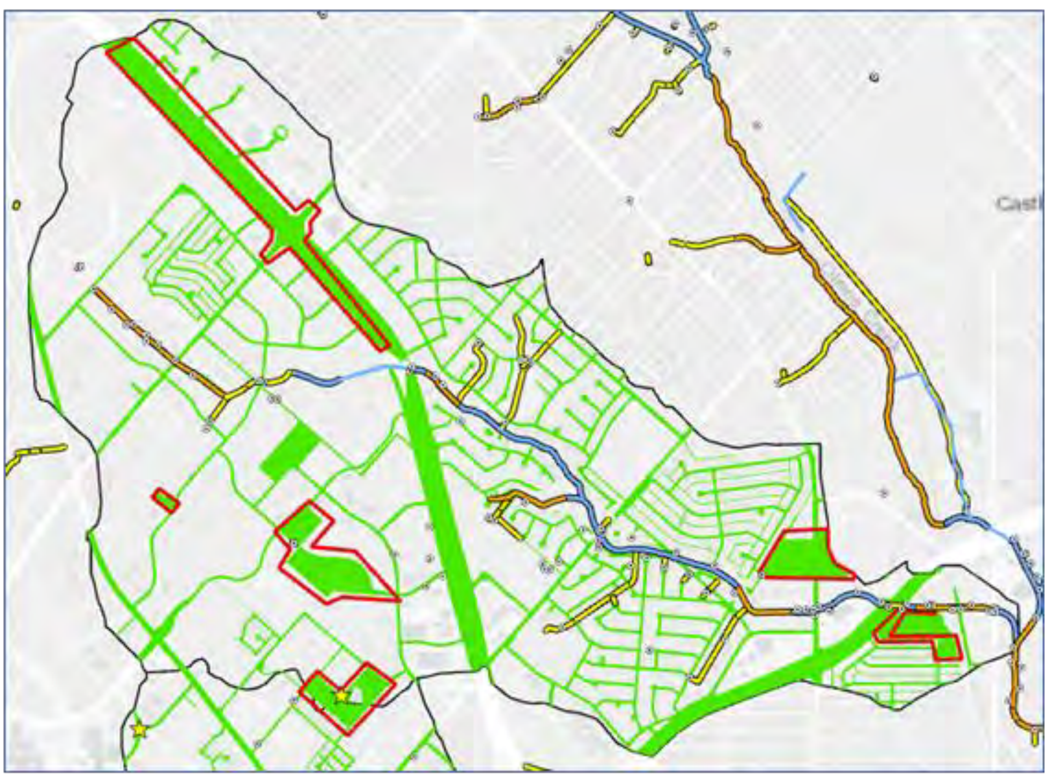


Figure 3. Subbasin 70 (black outline) with available land (green) and layers from the SA River Authority criteria, with the site selection boundaries (red outline).

Simple layer overlays and map cartography techniques were used to differentiate layers from one another or highlight a specific attribute, i.e., sarbcode or property owner. Every subbasin had a high level of development which made it challenging to find available land larger than one acre, e.g., subbasin 150. Another challenge was finding a site in subbasins where the floodplain was predominant. For example, the floodplain bisects subbasin 260 and 270 which created a split in the amount of available land to select from. A total of 59 sites were selected across the eight subbasins, all of which were reviewed for additional comment.

Appendix B. Modeling Documentation – Pre-Modeling Checklist

TCEQ Nonpoint Source Program

Modeling Input Planning Checklist

(July 2017)

Purpose:

To facilitate communication between the modeling team, TCEQ, and stakeholders regarding inputs to the watershed model(s) being developed for stakeholder watershed-based planning. Feedback at the beginning of the process will help to get everyone on the same page and prevent issues down the road.

Goals:

- Ensure sufficient up-front planning conducted prior to jumping into modeling.
- Get stakeholder comments on model inputs at the beginning of the project rather than the end.
- Identify quality local sources, if available, rather than national or statewide sources.
- Have stakeholders "ground truth" modeling input data and assumptions for their watershed.
- Identify any significant data gaps and determine if necessary to collect the additional data or move on acknowledging data gap and having a work around.

QAPP Development:

This checklist should be filled out at the beginning of the modeling project in association with the development of the QAPP. This checklist is meant to compliment the QAPP planning process and does not replace the QAPP.

Review Process:

The contractor will submit the checklist to TCEQ for review. Once approved by TCEQ, the contractor will develop a presentation to present to stakeholders for their feedback regarding modeling inputs. Final adjustments to proposed inputs will be made and sent to TCEQ (stakeholders as well, if deemed necessary). Modeling can begin once QAPP executed and checklist approved by TCEQ.

Notes: This document only covers modeling of existing loadings and future loadings if no BMPs implemented. Future scenarios associated with implementation of BMPs are not covered. Not all inputs to a model are included in this checklist. There may be some questions or data that is not applicable to your project (e.g. calibration not necessary for SELECT model). It is okay to add N/A for questions if this is the case. It is difficult to create a "one size fits all" checklist so TCEQ Project Managers should review and make adjustments or additions to this checklist prior to sending to your contractor depending on your knowledge of the project.

Electronic File Backup Procedure

Describe your electronic file backup procedure. Include frequency. (excerpted from the 90204_2.2 Modeling QAPP) _____>

Archives/Data Retention

Complete original data sets are archived on electronically and retained on-site by the San Antonio River Authority for a retention period specified in Table A9.1 Project Documents and Records.

The River Authority's backup system is based on Veeam Backup and Replication v9.5 software. This software runs on a virtual server in our data center and is closely integrated with VMWare vCenter Server. Our target storage device is a new DataDomain DD6300 data de-duplicating storage device. The way the system works is through taking snapshots at prescribed times throughout the day. These snapshots are saved in the DataDomain DD6300. All servers are backed up a minimum of once a day and file servers are backed up every 6 hours. Once a day file servers and financial servers are copy from the DataDomain DD6300 to our Disaster Recovery Center located at Martinez II Administration Office Data Center to another DataDomain. Once a month the system runs a full backup that is kept for a period of 12 months. At that point it is allowed to be overwritten if necessary. The system backs up servers by taking machine level snapshots and does not use file level backups and the Veeam server maintains a database of these snapshots so access to these files can only be done through the Veeam server. Access to this server is limited to only specified IT personnel. The replication from one DataDomain to the other is through a proprietary protocol called DDBoost which encrypts the transmission and sends only de-duplicated data across the wire. This is inherently secure because only the DataDomains share the encryption database keys between themselves, so that only these two DataDomains can unlock the data.

San Antonio River Authority ARCHIVES POLICY
This policy provides guidance on staff management of records to be considered for the Archives (Archives) of the San Antonio River Authority (the River Authority). The River Authority's main Archives may be maintained by a qualified third party (the Repository) and is currently located at the Institute of Texan Cultures under the management of the University of Texas San Antonio Archives Department. A second Archives, consisting of documents frequently utilized by River Authority staff, is housed on-site in the Archives Room at the San Antonio River Authority's 100 E. Guenther Street location.
https://saranet.sara-tx.org/wp-content/uploads/2018/06/policy_archives_final_20180516.pdf

Backup/Disaster Recovery

Electronic files are backed up using Veeam Backup and Replication software version 9.5 which runs on a virtual server in the River Authority's data center and is closely integrated with VMWare vCenter Server. The target storage device is a DataDomain DD6300 data de-duplicating storage device.

- All servers are backed up a minimum of once a day
- File servers are backed up every 6 hours. The project folder resides on a file server and will be backed up at this frequency.

Once a day file servers and financial servers are copied from the DataDomain DD6300 to our Disaster Recovery Center located at Martinez II Administration Office Data Center to another DataDomain. This is performed through a proprietary protocol called DDBoost which encrypts the transmission and sends only de-duplicated data across the wire. This is inherently secure because only the DataDomains share the encryption database keys between themselves, so that only these two DataDomains can unlock the data.

Once a month the system runs a full backup that is kept for a period of 12 months. The system backs up servers by taking machine level snapshots and does not use file level backups. The Veeam server maintains a database of these snapshots so access to these files can only be done through the Veeam server. Access to this server is limited to only specified IT personnel.

To recover files, the team member should submit an IT Helpdesk Ticket. The files can be recovered immediately to the version that was backed-up within the last 6 hours.

Elevation Data

Source: <FUGRO>	Resolution: <1-Foot>	Notes: < _____>

Is the topography of the watershed relatively flat such as in the coastal plain? Yes ☐ No ☒

If yes, briefly explain general flow patterns in the watershed and justify the elevation source selected as being adequate to capture these flow patterns. < N/A___>

Are there instances of normal flow direction being reversed in the watershed? Yes ☐No ☒ Maybe ☐

If yes or maybe, please explain. < N/A_____>

Is LIDAR being used? Yes ☒ No ☐ If not, please explain why. < N/A___>

Watershed Boundary

Source or Method: <The source is described in: San Antonio River Authority, 2019g. HSPF Modeling for Water Quality Master Planning of Salado Creek, Upper San Antonio River, and Leon Creek Watersheds. Nonpoint Urban Runoff Modeling and BMP Strategies- Volume V. Report developed for the San Antonio River Authority, San Antonio, Texas, March 31, 2019>	Notes: <None._____>

What method or tool was used or will be used to delineate the watershed boundary? <Arc Hydro or similar GIS tool supplemented with manual delineation.> Briefly explain. <Arc Hydro or similar GIS tool will be used to delineate the drainage areas for the selected BMP sites using the high-resolution DEM data. The delineated drainage areas will be reviewed and manually adjusted as needed to take into account features such as storm sewer systems.>

Are there flood or irrigation control measures such as flood gates that can be open or shut in the watershed? Yes ☐No ☒ Maybe ☐

If Yes or maybe, how are these controls being taken into account during the watershed boundary delineation? <_ N/A____>

Are there any areas in the watershed that do not behave as a typical watershed such as a sink? E.g. stream losses in Edwards aquifer recharge area. Yes ☐No ☐ Maybe ☒

If yes or maybe, how are these being taken into account in the model? <_____>

Has this boundary been reviewed by the local drainage district? Yes ☒No ☐

Land Use or Landcover

Source: <San Antonio River Authority>	Year: <2017 _>	Notes: <The 2017 landuse data will be used to update the landuse in the HSPF model.>

Land Use or Landcover (LULC) is extremely important to modeling overland flow and NPS loadings to the waterbody. Different land uses will have different flow and time of concentration factors built into the model. NPS pollutants must also be distributed over appropriate land uses in the watershed (e.g. normally livestock input into the model would not be distributed on urban land). Accurate and up-to-date LULC classifications are vital.

Does the LULC source selected sufficiently reflect the actual land uses of the watershed? <Yes>

What are some potential issues that you see with the source (e.g. not a recent date, misclassifications noticed, finer scale resolution needed, etc.)? <No>

Has there been significant development or land use changes in the watershed since the LULC source was published? <No>

Should revisions/refinement of the selected source or a local LULC watershed study be considered before proceeding with modeling? <No>

Please fill in the table for the land uses within the watershed. Also, please attach a LULC watershed map.

This information will be provided in the future with the modeling documentation.

Land Cover	Acres	% of Watershed Total
11	4670.872	4.923955
12	8107.564	8.546858
21	1732.299	1.82616
22	652.693	0.688058
23	10646.11	11.22295
24	23961.19	25.25948
25	3135.037	3.304903
31	16085.98	16.95757
41	4214.319	4.442664
51	15866.66	16.72636
61	473.0212	0.498651
71	1947.84	2.05338
72	2186.904	2.305397
81	630.4236	0.664582
91	549.2627	0.579023

Flow Data (Add rows as needed)

Stream Location	Source	Time Period Available	Frequency	Notes
<Multiple_____>	<__USGS___>	<_2007-2010____>		The base model is calibrated to USGS flow data. See San Antonio River Authority, 2019g. HSPF Modeling for Water Quality Master

				Planning of Salado Creek, Upper San Antonio River, and Leon Creek Watersheds. Nonpoint Urban Runoff Modeling and BMP Strategies-Volume V. Report developed for the San Antonio River Authority, San Antonio, Texas, March 31, 2019.

If no daily flow data is available, what is available? What impact does this have on the modeling effort? <No stream flow data is needed. "Workplan For Site-Scale Modeling (Task 5) item 6a of the QAPP says, "For one selected site, conduct GSSHA modeling and compare the GSSHA output hydrograph per landuse against the site-scale HSPF model output at the influent location to BMP. If inconsistent, then adjust the HSPF model hydrologic parameters in a calibration/validation process so that the HSPF output hydrograph can match the GSSHA ones. The calibrated hydrologic parameters will then be applied to the site-scale HSPF models of the remaining 7 sites.">

Note: If no flow data is available you may want to consider collecting flow data as initial step of project.

What is the time period the model will be calibrated to? <The modeling will use a design storm event.>

Is there sufficient flow data for this period for calibration? <See above.>

Water Quality Data

Source(s): <TCEQ SWQM database_____>	Notes: <The base model is calibrated. See San Antonio River Authority, 2019g. HSPF Modeling for Water Quality Master Planning of Salado Creek, Upper San Antonio River, and Leon Creek Watersheds. Nonpoint Urban Runoff Modeling and BMP Strategies-Volume V. Report developed for the San Antonio River Authority, San Antonio, Texas, March 31, 2019.>

Please list the parameters/Pollutants that will have modeled loadings to the water body. <*E. coli* bacteria, temperature, dissolved oxygen, carbonaceous biochemical oxygen demand, nitrate nitrogen, ammonia nitrogen, organic nitrogen, total phosphorus, orthophosphorus, TSS>

Please note that all pollutants listed in the Texas Integrated Report in connection with impairments or concerns for the water body(s) need to be addressed in the WPP.

Is there sufficient data collected for each of the parameters being modeled? Yes ☒No ☐ Maybe ☐

If No or Maybe, what are the data gaps? <_N/A____>

Is there sufficient water quality data available for the calibration period? Yes ☒No ☐ Maybe ☐

Is there sufficient geographic distribution of water quality stations? Explain. <The base model is well calibrated using available water quality data and the information can be found in San Antonio River Authority (2019g)>

Seasonal Variations

Are there significant seasonal variations to flow and inputs that need to be considered in the model? Yes ☐ No ☒ E.g. irrigation return flows during growing season, waterfowl migration, etc.

If yes, please describe how these will be accounted for in the model. <__N/A___>

Is there spring flow in the watershed? Yes ☒No ☐ Maybe ☐

If Yes or Maybe, please describe < Spring flow was considered in the base model. The information can be found in San Antonio River Authority (2019g). But spring flow is not expected to be relevant for the selected sites.>

Are there any atypical sources of flow in the watershed? Yes ☐No ☒ Maybe ☐

If Yes or Maybe, please describe <_N/A____>

Buffer Weighting

Do you plan to apply any buffer weighting? For example, pollutant sources nearer to the stream will be modeled with a higher likelihood of reaching the stream? Yes ☐No ☒ Maybe ☐

Please explain: <Not required in QAPP and not needed due to modeling site-scale already.>

Septic Systems

Will be included in Model? Yes ☐No ☒

Source: <__N/A___>	Notes: <Base model included no OSSF due to no data found. Not required in QAPP and not expected to have septic systems in drainage areas of selected sites.>
Failure Rate % and Source*: <_N/A____>	
Pollutant Concentration and Source: <_N/A____>	
Land Uses applied to: <__N/A___>	
Method for calculating number in watershed: < N/A_____>	
Example Sources: 1) EPA national study in 2002 found failure rates averaged between 10-20% across U.S. (Onsite Wastewater Treatment Systems Manual 2002) 2) Texas average was found to be 12% according to Texas On-Site Council Study	

*Local input from local designated representative and stakeholders is required; or provide justification for why it cannot be obtained.

Are locations of septic systems known? Yes ☐ No ☒

If yes, briefly explain how locations of septic systems were identified. <_N/A____>

If no septic system locations available are you planning to collect this information? Yes ☐ No ☒

If not what will be your methodology for including septic systems in the model? <No OSSF data found during base model development and calibration_____>

Please justify the failure rate chosen. < N/A_____>

Dogs

Will be included in Model? Yes ☐No ☒

Source: <__N/A___>	Notes: <Not specifically modeled. The base model has been calibrated and the same loading parameters will be used. See San Antonio River Authority, 2019g. HSPF Modeling for Water Quality Master Planning of Salado Creek, Upper San Antonio River, and Leon Creek Watersheds. Nonpoint Urban Runoff Modeling and BMP Strategies-Volume V. Report developed for the San Antonio River Authority, San Antonio, Texas, March 31, 2019.>
Pollutant Concentration: <_N/A____>	Source: <_N/A____>
Number of houses in watershed: <__N/A___>	Source: <__N/A___>
Percentage of homeowners picking up pet waste: <N/A____>	Source: <__N/A___>
Total calculated for watershed show work: <_N/A____>	
Land Uses applied to: <_N/A____>	
Example Source: 1) American Veterinary Medical Association's 2012 U.S. Pet Ownership & Demographics Sourcebook - 44% of households in Texas own dogs and average of 1.6 dogs in each house.	

Are there a significant amount of stray dogs in the watershed? <_Unknown____>

Sanitary Sewer Overflows

Will be included in Model? Yes ☒No ☐

Source: <SSO considered in base model. Details in report "San Antonio River Authority, 2019d. Isolation of Sanitary Sewer Overflows for HSPF Modeling of SARA Watersheds. Nonpoint Urban Runoff Modeling and BMP Strategies- Volume IV. Report developed for the San Antonio River Authority, San Antonio, Texas, March 31, 2019.>	Notes: <__SSO flow data provided by SAWS___>
Pollutant Concentration: <_modeled using raw sewage combined with runoff concentrations – see 2019g for details____>	Source: <_San Antonio Water System>
Land Uses applied to: <_SSO modeled as point sources into stream directly____>	
Method for calculating number in watershed: <_see 2019g____>	
Example Sources and Guidance: TCEQ regional field office should have this information. It should contain system operator, duration of event, received date, volume of event, incident source, cause, receiving water body, and significance of incident. Obtain at least one year's worth of data. Concentrations can be obtained from EPA literature value for medium concentration EPA literature value for medium concentration https://www.epa.gov/npdes/2004-npdes-cso-report-congress SSOs are episodic rather than chronic load conditions, and therefore average volumes may underrepresent acute conditions. Stakeholders must decide whether to model SSOs as daily averages, or find alternate means of including them as peaking factors. 2004 NPDES CSO Report to Congress shows 3 concentrations depending on type of weather. https://www.epa.gov/npdes/2004-npdes-cso-report-congress . I think the lower concentration during wet weather would be because inflow and infiltration to the system is likely higher and dilutes sewage.	

SSO Fecal Coliform Concentration

The estimation considers the impacts on streams of three representative fecal coliform concentrations:

- Dilute wastewater, with a fecal coliform concentration of 500,000 counts per 100 mL (typical for a wet weather SSO).
- Medium strength wastewater, with a fecal coliform concentration of 10,000,000 counts per 100 mL (middle range for dry-weather SSOs).
- Concentrated wastewater, with a fecal coliform concentration of 1,000,000,000 counts per 100 mL (upper range for dry-weather SSOs).

The decay of fecal coliform bacteria was not included because the analysis was limited to the point of mixing where impacts are likely greatest, and did not consider effects, if any, as the bacteria moved downstream.

Are SSOs mainly related to infiltration and inflow due to episodic storm events or are there serious problems with the collection systems that may contain continuous leaks? < _Both – see SAWS reports for details____>

Sewer System GIS layers or maps

Do you plan to obtain sewer system maps and utilize for modeling SSOs or septic systems?
Yes ☐No ☒ Maybe ☐

If so, please list the systems you will need to obtain data for. <____N/A___>

Wastewater Outfalls

Are there any local studies on wastewater outfall flow and concentration that you will be using or will you use the permit and associated data reported to TCEQ and EPA? < Yes, wastewater flows and concentrations used in calibration of base model, please see the report "San Antonio River Authority (2019g)">

Will the flow and concentrations input into the existing loadings model be at the max daily average permit level or the average reported levels? < The details are in the 2019g report mentioned above>
Why? <reported levels used for base model calibration and permit levels to be used in future-condition modeling.>

Is there any current wastewater reuse or planned reuse in the future? Yes ☐ No ☒ NA

If so, how will this be taken into account in the model? < Any know WW reuse data incorporated into the base model during the calibration process____>

How will future increases in water use be taken into account? < Assume future WW at permitted levels ____>

Guidance for obtaining wastewater information.

ID Examples:

State ID: WQ0010475-002

EPA ID: TX0027782

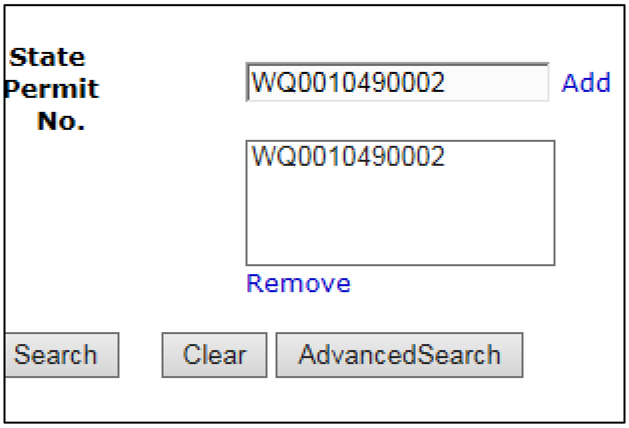
FRS ID: 110009780521

Sources:

EPA ECHO - https://echo.epa.gov/ Discharge data can be downloaded for WWTFs individually. Example webpage https://echo.epa.gov/detailed-facility-report?fid=110009780521

EPA ICIS – Can batch download WWTF reported discharge data. Must obtain permission to access. https://ssoprod.epa.gov/sso/jsp/ICIS_Login.jsp

TCEQ Wastewater Permit Query - http://www1.tceq.texas.gov/wqpaq/ State ID required to pull permit information (e.g. WQ0010490002)



Fertilizer Application

Will be included in Model? Yes ☐No ☒

Source: <__N/A___>	Notes: <_Fertilizer application not specifically modeled in urban watersheds. However, nutrients are simulated in the base model and calibrated to available data.____>
Pollutant Concentration: <__N/A___>	Source: <__N/A___>
Land Uses applied to: <N/A_____>	

Please briefly describe how this will be incorporated into the model. <__N/A___>

Will seasonal fluctuations be taken into account? <___N/A__>

Livestock (Repeat Table as needed)

Will be included in Model? Yes ☐No ☒

Species: <_N/A____>	
Source: <_N/A____>	Notes: <_N/A____>
Number and Density: <_N/A____>	Source: <__N/A___>
Pollutant Concentration: <_N/A____>	Source: <__N/A___>
Land Uses applied to: <_N/A____>	
Method for calculating number in watershed: <N/A_____>	
Example Sources: 1) USDA National Agriculture Statistics Service County-level agricultural census data	

2) Local knowledge

Deer

Will be included in Model? Yes ☐No ☒

Source: <_N/A____>	Notes: <__N/A___>
Number and Density: <_N/A____>	Source: <_N/A____>
Pollutant Concentration: <__N/A___>	Source: <_N/A____>
Land Uses applied to: <__N/A___>	
Method for calculating number in watershed: <_N/A____>	
Example Sources: 1) Texas Parks and Wildlife Department Resource Management Unit data for the area. Contact local office and get most up to date. 2) Local knowledge	

Feral Hogs

Will be included in Model? Yes ☐No ☒

Source: < N/A_____>	Notes: <_N/A____>
Number and Density: <_N/A____>	Source: <_N/A____>
Pollutant Concentration: <_N/A____>	Source: <_N/A____>
Land Uses applied to: <_N/A____>	
Method for calculating number in watershed: <_N/A____>	
Example Sources: 1) Texas AgriLife. A 2011 report by Texas A&M Institute of Renewable Natural Resources found Feral Hog Density in Texas from reported studies ranged from 1.33 hogs/square mile to 2.45 hogs/square mile. Had a 95% confidence interval. 2) Local knowledge	

Other Significant Wildlife (Repeat Table as needed)

Will be included in Model? Yes ☐No ☒

Species: <_N/A____>	
Source(s): <__N/A___>	Notes: <___N/A__>
Number and Density: <__N/A___>	Source: < N/A_____>
Pollutant Concentration: <_N/A____>	Source: < N/A_____>
Land Uses applied to: <_N/A____>	
Method for calculating number in watershed: <__N/A___>	

Are there other significant wildlife sources in the watershed that aren't listed in this checklist?
Yes ☐ No ☒ (E.g. Arroyo Colorado watershed has Javelina and Nilgai.)

Please list other significant wildlife sources and whether you plan to include in model. N/A

Wildlife Unknown

Will be included in Model? Yes ☐No ☒

Source(s): N/A	Notes: N/A
Pollutant Concentration: < N/A_____>	Source: <_ N/A ____>
Land Uses applied to: <_ N/A ____>	
Method for calculating number in watershed: <_ N/A ____>	

Bacterial Source Tracking

Has bacterial source tracking been completed or is planned for the watershed being modeled?

Yes ☒ No ☐ If so, what did results show? <__ Please see the attached report titled, *Basin Wide and County BST summaries* . _>

Is this information planned to support modeling in anyway? Yes ☐ No ☒

If yes, please explain. <_ N/A ____>

Urban Stormwater

Will be included in Model? Yes ☒No ☐

Source: <__See Report " San Antonio River Authority (2019g) ___>	N/A
Pollutant Concentration: <_ N/A ____>	Source: < N/A _____>

Are the pollutants of concern in the urban stormwater in the watershed? <Yes, E.coli, etc._____>

Do any of the Municipal Separate storm sewer systems collect water quality samples of their systems?
Yes ☒No ☐ If so, please describe data collected. <___MS4 data collected by SAWS at limited MS4 outfall locations. Data set considered but not specifically applied because the data set is too small and the MS4 sampling locations are too limited for subwatershed-scale base model development and calibration.__>

Industrial Activity

Will be included in Model? Yes ☒No ☐

Is there any significant industrial activity in the watershed that may contribute the pollutants of concern?
Yes ☒No ☐ Maybe ☐ If so, please describe. <_Permitted industrial wastewater contained in TCEQ database were included as point source in the base model.____>

Are you able to obtain information on these sources and there contribution? Yes ☒No ☐ Maybe ☐ If so, please describe. <_Permitted industrial flows and self reporting data obtained from TCEQ. ____>

Illegal Dumping

Will be included in Model? Yes ☐No ☒

Source: <___N/A__>	Notes: <__N/A___>
Land Uses applied to: <_N/A____>	
Method for calculating number in watershed: < N/A_____>	

Where are the specific areas of concern in the watershed? <_N/A____>

Do the illegal dump sites usually contain trash that would contribute to pollutant of concern? <N/A____>

Are their many dump sites near streams? <__N/A___>

Existing Ag Land Water Quality Management Plans

Will be included in Model? Yes ☐No ☒

Source: <N/A_>	Notes: <No significant agricultural land expected in urban watersheds._____>
Source: This information can be obtained from the Texas State Soil and Water Conservation Board and the United States Department of Agriculture	

Is there a significant number of acres in the watershed under a WQMP plan? Yes ☐No ☐

Please describe how this will be incorporated into the model. N/A

Major Existing BMPs

Are there any major existing BMPs that should be included in the model? Yes ☐ No ☒ (e.g. large wetland filter system, instream aeration structures, etc.)

Please list the major existing BMPs that should be considered for incorporation into the model.

N/A

Future Scenario Baseline Modeling

Future scenario baseline modeling is the next step after existing baseline modeling. It is the scenario of what would happen if no new BMPs were implemented to reduce existing loadings. Future scenario baseline modeling should include projections of waste water treatment plant growth, water reuse projections, land use changes such as urban development, etc.

No Future scenario modeling will be conducted under this project.

How will future increases in water use be taken into account? <__NA___>

How will land use be taken into account? <__NA___>

How will water reuse be takin into account? <__NA___>

Will anything else be taken into account? <__NA___>

Appendix C. Additional Details on the HSPF Modeling for BMP Performance Evaluation

Sensitivity Analyses

Sensitivity analyses were conducted to determine the effect of changing model input parameters or variables on the model outcome. Selected HSPF model parameters relevant in model calibration were changed by +/- 20% one at a time. The changes in model calibration statistics due to sensitivity analysis were then summarized and reviewed to identify sensitive model parameters and resulting statistics. Details of the calibration are documented in Attachment A, "Calibration of Site-Scale HSPF Model".

Hydrologic Parameters

During calibration, the HSPF hydrologic parameters were adjusted so that the flow hydrographs generated by HSPF at the inlet of the bioswale were as consistent with the Gridded Surface Subsurface Hydrologic Analysis (GGSHA) results as possible. Table M-1 below is the same as Table IV-1 in Attachment A. The table shows the relevant hydrologic parameters, the values adopted after the calibration process, and the typical and possible ranges of each parameter from BASINS Technical Note 6.

As discussed in the Attachment A, the values adopted after calibration are at the limits of the possible range. For the purpose of the sensitivity analyses, the parameters were adjusted +/- 20% even if the adjustments would result in the parameters falling outside the possible ranges.

Table M-1 HSPF IMPLND Model Parameters for Hydrology

HSPF Parameter	Description	Units	Typical Range		Possible Range		Values Adopted
			Min	Max	Min	Max	
LSUR	Length of overland flow	feet	50.0	150.0	50.0	250.0	250.0
SLSUR	Slope of overland flow plane	ft/ft	0.010	0.050	0.001	0.150	0.001
NSUR	Manning's n for overland flow	none	0.030	0.100	0.010	0.150	0.150
RETSC	Retention storage capacity	inches	0.030	0.100	0.010	0.300	0.300

The results of the sensitivity analyses are presented in Table M-2. The parameters LSUR, SLSUR, and NSUR affect routing but not the runoff volume. On the other hand, RETSC is a storage factor. Therefore, changes in RETSC resulted in changes in the runoff volume. Moreover, the peak flow also appears to be most sensitive to RETSC.

Table M-2 Sensitivity Run Results for Hydrologic Parameters

Variable	Units	GSSHA	HSPF								
			Calibration	LSUR -20%	LSUR +20%	SLSUR -20%	SLSUR +20%	NSUR -20%	NSUR +20%	RETSC -20%	RETSC +20%
Runoff Volume	ac-ft	0.928	1.056	1.056	1.056	1.056	1.056	1.056	1.056	1.102	1.010
Peak Flow	cfs	1.520	1.510	1.537	1.475	1.490	1.522	1.537	1.475	1.570	1.427
			Difference of HSPF results from GSSHA results								
Runoff Volume			13.79%	13.79%	13.79%	13.79%	13.79%	13.79%	13.79%	18.75%	8.84%
Peak Flow			-0.66%	1.12%	-2.96%	-1.97%	0.13%	1.12%	-2.96%	3.29%	-6.12%

EC Loading Parameters

In HSPF the loading from the drainage area is modeled as a buildup-washoff process. In the calibration, the loads calculated by HSPF were compared to the loads of the SUSTAINOPT input in the proof-of-concept study. As discussed in the calibration memo, the relevant parameters for EC loads are the following IMPLND parameters:

- SQO is the initial storage of the constituent.
- ACQOP is the rate of accumulation of the constituent.
- SQOLIM is the maximum storage of the constituent.
- WSQOP is the rate of surface runoff which will remove 90 percent of stored constituent per hour.

The values adopted in the calibration are shown in Table M-3, which is Table V-1 in Attachment A. The initial storage was not considered in the sensitivity analyses because it was established by running the model with a repeated rainfall pattern of one wet day followed by three dry weeks until equilibrium was established.

Table M-3 HSPF IMPLND Model Parameters and Adopted Values for EC Calibration

Landuse	SQO (10^6/ac)	ACQOP (10^6/ac-day)	SQOLIM (10^6/ac)	WSQOP (in/hr)
Residential High	0.050	12,800	89,600	1.0
Commercial	0.050	6,400	44,800	1.0
Transportation	0.050	6,400	44,800	1.0

The results of the sensitivity analysis are presented in Table M-4. Model results are least sensitive to ACQOP. The most sensitive parameter seems to be SQOLIM since changing it by +/- 20% resulted in significant changes in total EC load, peak EC concentration and flow-weighted GM. WSQOP is also a sensitive parameter and seems to effect a larger change in peak EC concentration than SQOLIM.

Table M-4 Sensitivity Run Results for Watershed Load Parameters

Variables	Units	SUSTAINOPT Input	Site-Scale HSPF						
			Calibration	ACQOP -20%	ACQOP +20%	SQOLIM -20%	SQOLIM +20%	WSQOP -20%	WSQOP +20%
Total EC load	MPN	4.06E+11	4.21E+11	4.04E+11	4.30E+11	3.45E+11	4.89E+11	4.33E+11	4.07E+11
Peak EC concentration	MPN/dL	97,710	97,533	94,026	99,285	79,649	113,745	119,957	82,204
Flow-weighted GM EC	MPN/dL	30,948	23,068	22,122	23,596	18,951	26,785	20,027	24,578
			Difference of HSPF results from SUSTAINOPT Input						
Total EC load			3.65%	-0.45%	5.91%	-14.95%	20.50%	6.64%	0.18%
Peak EC concentration			-0.18%	-3.77%	1.61%	-18.49%	16.41%	22.77%	-15.87%
Flow-weighted GM EC			-25.46%	-28.52%	-23.76%	-38.76%	-13.45%	-35.29%	-20.59%

Findings

The sensitivity analysis results showed that RETSC (retention storage capacity) is the most sensitive hydrologic parameter and SQOLIM (maximum storage of the constituent) is the most sensitive parameter for calculating drainage area loads. Another parameter that typically would be important to model output EC levels is the decay coefficient. However, with the model calibration run having essentially all inflow to the bioswale lost through infiltration, changes in the decay coefficient would not affect the model results so it is not sensitive in this specific bioswale modeling.

Additional BMP Performance Evaluation

The workplan for site-scale modeling (Task 5) in the QAPP calls for specifying the retention capacity, inflow rate capacity, flow-through rate capacity, and load reduction of the BMPs. The load reduction in terms of percentage removal for each constituent and each site has been reported in the above sections. Retention capacity, inflow rate capacity, and flow-through rate capacity are presented in Table N-1. These are calculated based on the 4-year simulation.

Table N-1 Retention Capacity, Inflow Rate Capacity, and Flow-through Rate Capacity of BMP

Subbasin	BMP	WQV	Retention capacity (Note 1)	Peak inflow (Note 2)		Inflow rate capacity	Peak outflow through BMP (Note 3)		Flow-through rate capacity
		(ac-ft)		(ac-ft/hr)	(cfs)	(x WQV/hr)	(ac-ft/hr)	(cfs)	(x WQV/hr)
70	Bioswale N	0.0628	22.3%	0.0278	0.3363	0.4426	0.002868	0.03470	0.04567
70	Bioswale S	0.0518	22.8%	0.0224	0.2708	0.4320	0.002364	0.02860	0.04564
70	Extended Detention N	0.2487	0.6%	0.2687	3.2513	1.0804	0.005744	0.06950	0.02310
70	Extended Detention S	1.1350	0.5%	1.2264	14.8394	1.0805	0.026347	0.31880	0.02321
150	Bioretention	0.6069	8.2%	1.1592	14.0263	1.9100	0.031099	0.37630	0.05124
260	Bioretention N	0.2850	8.5%	0.5163	6.2472	1.8116	0.014521	0.17570	0.05095
260	Bioretention S	1.3969	8.6%	2.5092	30.3613	1.7963	0.071545	0.86569	0.05122
270	Bioretention	0.1731	9.7%	0.2711	3.2803	1.5661	0.008760	0.10600	0.05061
310	Bioswale	0.0189	10.0%	0.0260	0.3142	1.3741	0.000861	0.01042	0.04556
310	Bioretention	0.1758	9.1%	0.2925	3.5393	1.6638	0.008851	0.10710	0.05035
330	Bioretention N	0.0982	29.9%	0.1672	2.0231	1.7026	0.004893	0.05921	0.04983
330	Bioretention S	0.0882	8.9%	0.1477	1.7872	1.6746	0.004314	0.05220	0.04891
420	Bioretention W	0.0836	10.7%	0.1335	1.6154	1.5969	0.003530	0.04271	0.04222
420	Bioretention S	0.1069	8.0%	0.2554	3.0905	2.3892	0.004479	0.05420	0.04190
560	Bioswale	0.5708	76.6%	0.6155	7.4474	1.0783	0.025710	0.31109	0.04504

Notes:

1. Retention capacity is reported as the % of inflow volume removed in the 4-year simulation.
2. Peak inflow is the maximum hourly inflow of the 4-year simulation.
3. Peak outflow through BMP is the the maximum hourly outflow of the BMP excluding overflow.
   For bioretention/bioswale, this is essentially the filtration rate through the soil media.
   For extended detention, this is the orifice outflow.

The retention capacity refers to the flow removed by evapotranspiration and/or infiltration. Extended detention ponds have very low retention capacity because the water is only detained for a short time. For bioretention and bioswale, the underdrain layer was modeled to fill up and overflow. When the water level was below the top of the underdrain layer, the water was retained in the underdrain layer resulting in more evaporation.

For most of the bioretention/bioswale, no infiltration to the underlying soil was assumed because of HSG Type D soil. The retention capacities are typically about 8 to 10%. The bioswale in Subbasin 560 has a high retention capacity because an infiltration rate of 0.5 in/hr was used in the proof-of-concept modeling so that a substantial amount of flow infiltrated into the ground. Bioretention N of Subbasin 330 also has a higher than typical retention capacity because an infiltration rate of 0.1 in/hr was used for the HSG Type C soil. As discussed in Section E, the drainage areas for the bioswales in Subbasin 70 were determined proportionally from the area in the BMP Tool Database. However, the WQV in the BMP Tool Database was determined differently so that the bioswales in Subbasin 70 have larger WQV relative to the drainage area than the bioswale/bioretention in the other subbasins.

The inflow rate capacities are about one to two times WQV/hr. It was assumed that in detailed design the inlets would be sized to accommodate the expected peak flows. The bioswales in Subbasin 70 have lower inflow rate capacities because of the larger WQV relative to the drainage area as discussed above.

The flow-through rate capacities of bioswale/bioretention are typically between 0.04 and 0.05 WQV/hr and are mainly determined by the filtration rate of the soil media. The flow-through rate capacities of the extended detention ponds are lower and reflect the orifice flow.

BMP Inflow and Outflow Geometric Mean EC Levels

While very few, some of the results presented in this technical memorandum show the outflow geomean EC levels of a BMP being higher than the inflow levels. Some flow-weighted geomean EC levels also show similar results. One example is the Subbasin 70 Extended Detention N BMP where the inflow and outflow geomean EC levels are 72,383 and 72,668 #/dL, respectively, as listed in Table E-6. While the differences are small and may not be statistically significant, these "outflow EC levels higher than inflow EC levels" were investigated.

Exhibit O-1 shows example inflow and outflow timeseries of Subbasin 70's Extended Detention N BMP, where the inflow and outflow geomean EC levels are 78,305 and 82,506 #/dL, respectively, during this period of storm events. The plot shows that the BMP outflow hydrograph maintain a period of higher flow than the inflow after the storm peaks due to the detention effect of the BMP. With relatively lower inflow concentration after storm peaks and with BMP designed to be filled with the rising limb of the hydrograph, the water detained by the BMP has higher concentration for a period of time. This detaining higher concentration runoff and releasing it later is a reason why the geomean EC levels at the outflow could be slightly higher than the inflow.

Another reason is due to the BMP allowing more evaporation that result in less outflow than inflow near the tail end of the hydrograph. With EC levels increasing when flow volume approaches zero, the outflow geomean EC level could be higher than the inflow.

The cycles or steps in the outflow hydrograph and EC timeseries shown in Exhibit O-1 are due to evaporation that occurs during the day from the detention basin BMP. The steps are also due to the HSPF model updating the storage of constituent on the land surface once a day (at the beginning of the day) to account for accumulation and removal. Another complicating effect is that HSPF stops simulating decay when the flow depth drops to very low.

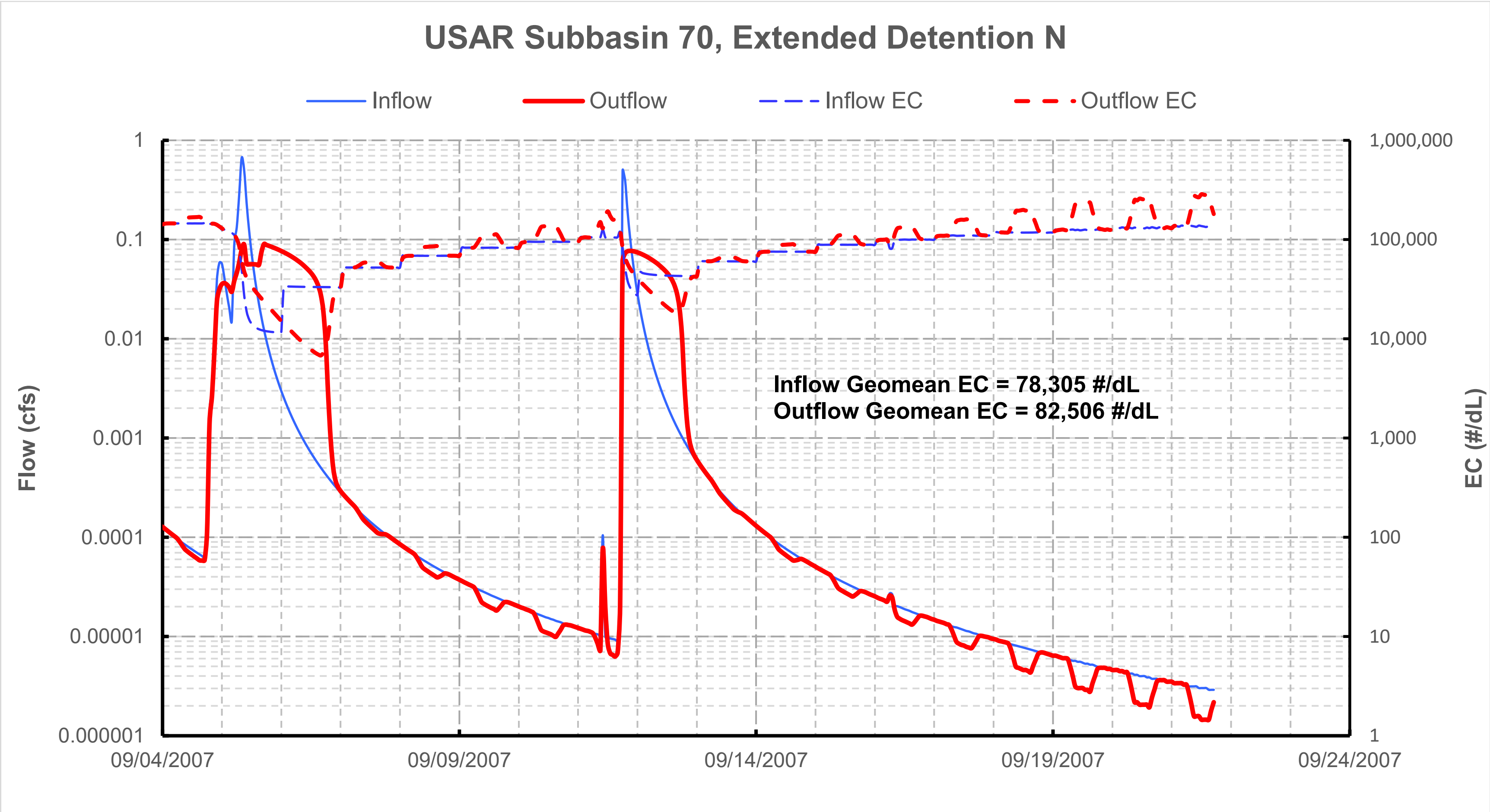


Exhibit O-1 Example BMP Outflow Geomean EC Levels Higher Than Inflow

Development of BMP Ranking Matrix

To assist with the selection of BMP site most suitable for modeling and performance evaluation, a BMP ranking matrix was developed using MS Excel. This ranking matrix is the first of its kind in San Antonio and it greatly helped with evaluation and selection of BMP sites within a subbasin. Attachment C provides a summary of the factors considered and the scoring involved in the BMP ranking process. Screen shots of an example BMP Ranking Matrix are also provided to the end of Attachment C.

References

City of San Antonio UDC LID. 2020. Code of Ordinances City of San Antonio, Texas, Chapter 35, Unified Development Code, January 29, 2020. https://library.municode.com/tx/san_antonio/codes/unified_development_code?nodeId=ARTIIUSPA_S35-210LOIMDENACHDEPRLINC.

Lockwood, Andrews & Newnam, Inc. 2019. Proof-of-Concept for Conducting Site-Scale Planning. Draft Technical Memorandum dated 08/17/2019.

San Antonio River Authority. 2019. Upper San Antonio River Watershed Protection Plan Implementation – Green Stormwater Infrastructure Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP). Revision date: 07/07/2020.

San Antonio River Authority. 2019. San Antonio River Basin Low Impact Development Technical Design Guidance Manual, Second Edition, May 2019.

U.S. Army Corps of Engineers. 2000. Hydrologic Modeling System HEC-HMS Technical Reference Manual, March 2000.

Attachment A
Calibration of Site-Scale HSPF Model

Introduction

A site-scale HSPF modeling was conducted under the Upper San Antonio River (USAR) Watershed Protection Plan Implementation – Green Stormwater Infrastructure Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP). This project was sponsored by the Texas Commission on Environmental Quality (TCEQ) and the San Antonio River Authority (The River Authority), and the HSPF modeling effort was conducted by Lockwood, Andrews & Newnam, Inc. (LAN).

The effort involved developing conceptual green stormwater infrastructure (GSI) designs at eight selected subbasins within the USAR Watershed with one GSI site per subbasin. The subbasin-scale HSPF model was refined to perform site-scale water quality (WQ) modeling at each of these eight GSI sites. The HSPF model was set up to simulate *E. coli* (EC) bacteria, water temperature, dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD), nitrate nitrogen, ammonia nitrogen, organic nitrogen, total phosphorus, orthophosphorus, and total suspended solids (TSS). The target constituent and the focus of the model calibration effort is EC.

One of the eight GSI sites was selected for HSPF model calibration purpose. The calibration involved comparing the HSPF results against those obtained from the corresponding two-dimensional (2D) Gridded Surface Subsurface Hydrologic Analysis (GSSHA) modeling using the same site, as well as the modeling of the Best Management Practices (BMP) using the SARA Enhanced BMP Tool. The comparison allowed adjusting HSPF model parameters from subbasin-scale to site-scale so that similar HSPF modeling approaches and parameters can be applied to the remaining seven GSI sites. This technical memorandum documents the development of the site-scale HSPF model, the calibration process, and results.

The River Authority's Proof-of-Concept Site-Scale Study in 2019

The River Authority, LAN, and the University of Texas at San Antonio (UTSA, through Innovironmental Solutions, LLC) conducted a "Proof-of-Concept for Conducting Site-Scale Planning" study in 2019 that involved a combination of models for site-scale planning. The project utilized GSSHA for hydrologic simulation, HSPF for WQ calculations, and SUSTAINOPT for BMP simulation. SUSTAINOPT is the BMP simulation and optimization engine of SUSTAIN developed by EPA. Details of the Proof-of-Concept project can be found in the draft technical memorandum entitled "Proof-of-Concept for Conducting Site-Scale Planning" (LAN, 2019).

In the proof-of-concept study, a site was selected in the Brooks Creek Development Area located mostly in USAR subbasins 480, 540, and 560, as shown in Exhibit II-1. The BMP selected was bioswale, and their locations and drainage areas are shown in Exhibit II-2. The topography and GSSHA grids are shown in Exhibit II-3. The grid cell size was 10 m x 10 m, and the GSSHA simulation time step was 1 minute.

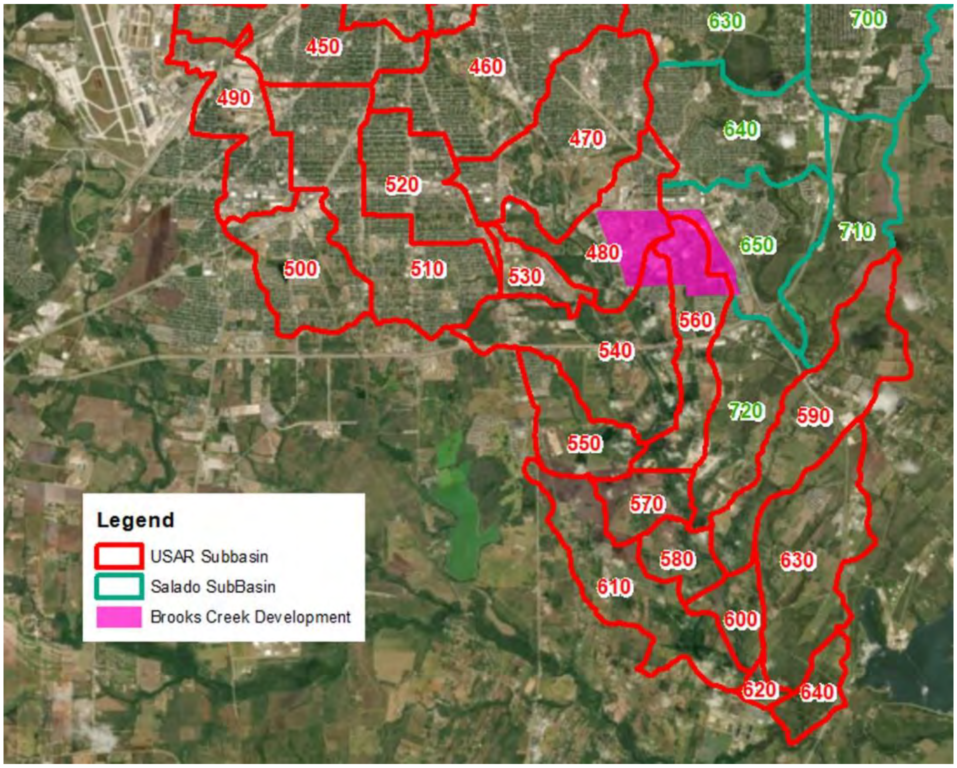


Exhibit II-1 Brooks Creek Development Area

A design storm was selected to conduct the proof-of-concept modeling based on the 1.8 inches per day (in/day) design rainfall defined in the River Authority's Low Impact Development (LID) Manual. Daily rainfall timeseries from Stations TX12961 and TX12970 were screened to show that three and four storm events at gages TX12961 and TX12970, respectively, had daily rainfall near 1.8 inches, as listed in Table II-1. Hourly rainfall patterns of these storm events were plotted to review hourly rainfall distributions, and the 4/30/2007 storm event was selected as a design storm because it has a smoother hyetograph and a cleaner three dry-day period after the event, as shown in Exhibit II-4.

In the proof-of-concept study, GSSHA was used to perform a 2D simulation of flows of the drainage areas. The flows computed by GSSHA were then input to HSPF to generate constituent wash-off loading timeseries. The flows from GSSHA and constituent loads from HSPF were then put into SUSTAINOPT to simulate the BMP process including flow routing and constituent removal through the BMP.

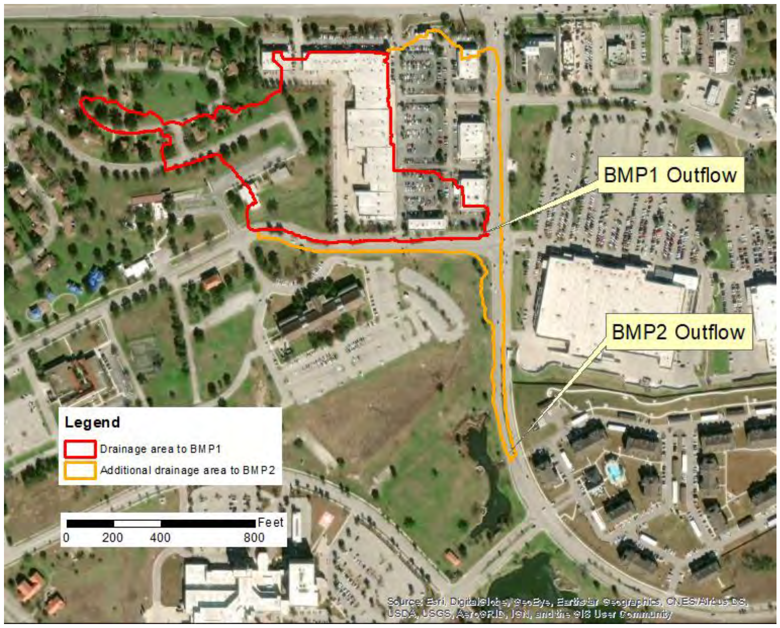


Exhibit II-2 Locations and Drainage Areas of BMPs Selected for Proof-of-Concept Study

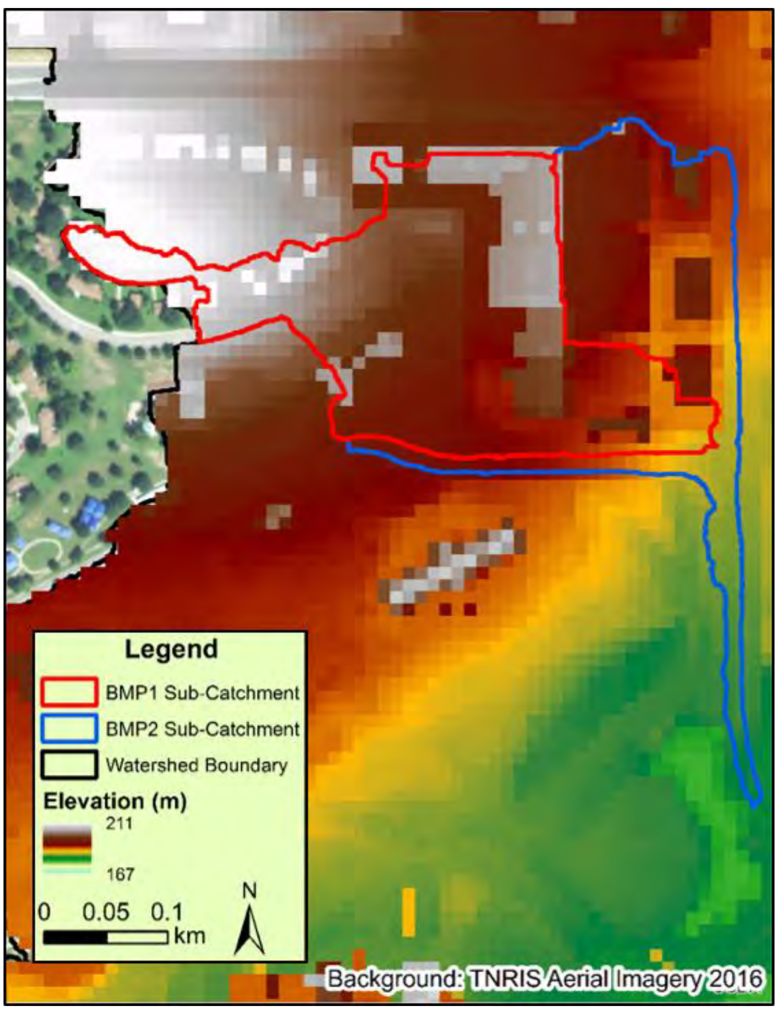


Exhibit II-3 Topography and GSSHA Grids

Table II-1 Screened Daily Rainfall Events from Stations TX12961 and TX12970

Date	TX12961	TX12970
03/30/07	1.83	0.65
03/11/07	3.28	1.76
03/13/07	0.44	1.71
04/30/07	0.30	1.81
06/27/07	1.84	0.17
02/03/10	1.61	1.81
09/07/10	1.73	6.25

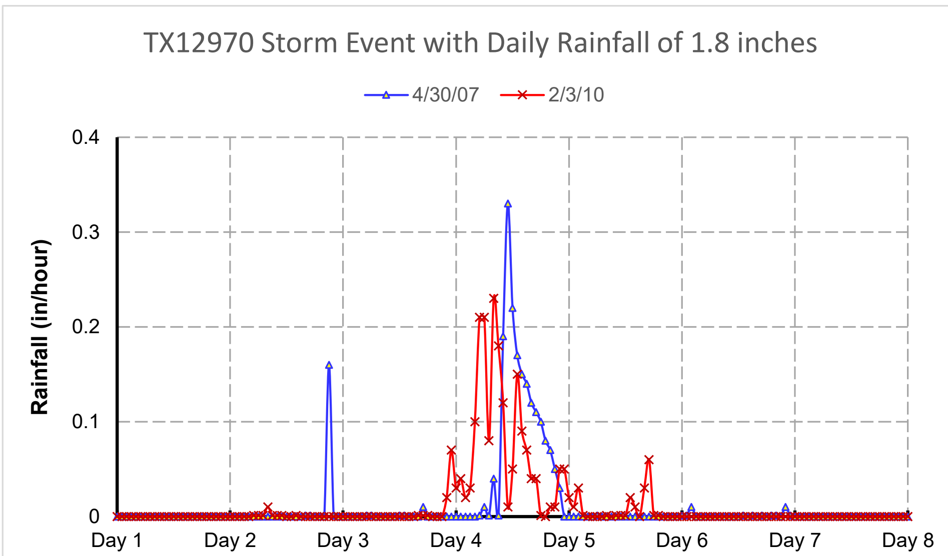


Exhibit II-4 Hourly Rainfall Patterns of Selected Storm Events

<u>Overview of Site-Scale HSPF Model Calibration Process</u>

It is recognized that GSSHA simulates 2D overland flow of a drainage area while HSPF is a lumped-parameter model. With this basic difference between the two models, the GSSHA results are considered more representative of a site-scale simulation. However, a 2D GSSHA modeling requires much substantial effort than HSPF including data collection, model set up, and model simulation time. Therefore, the purpose of the calibration is to allow adjusting HSPF model parameters to see if HSPF could generate similar results as GSSHA so as to allow conducting only HSPF simulations and avoid time-consuming and costly GSSHA modeling.

The site-scale model calibration was conducted by first creating a site-scale HSPF model for the same Brooks Creek Development Area BMP site as the 2019 proof-of-concept study by modifying the USAR subbasin-scale HSPF model. The modification included updating the land use characteristics in the model based on the data listed in Table III-1. The land use distribution and the impervious percentages listed in Table III-1 are the same as those used for the GSSHA modeling in the 2019 proof-of-concept study. As listed, commercial is the predominant land use in the drainage area to the BMP site.

The bioswale BMP was then set up in the site-scale HSPF model using the RCHRES operation. The same 1.8 in/day design rainfall used in the proof-of-concept study was used in the site-scale HSPF modeling. The initial conditions of the model were developed by executing the model with a repeated rainfall pattern of one wet day (with the 1.8 in/day design storm) followed by three dry weeks until equilibrium was established.

Table III-1 Land use Characteristics of Selected Site

Landuse	Total Area (ac)	Pervious (ac)	Impervious (ac)	% Impervious
Undeveloped meadow	0.494	0.494	-	0.0%
Residential high density	1.087	0.435	0.652	60.0%
Commercial	11.490	4.826	6.664	58.0%
Transportation	2.174	0.217	1.957	90.0%
TOTAL	15.245	5.972	9.273	60.8%

The site-scale HSPF model calibration involved the following major steps:

1. Calibration of the HSPF hydrologic parameters so that the flow hydrograph generated by HSPF at the inlet of the bioswale were as consistent with the GSSHA-generated flow hydrograph as possible.
2. Calibration of the HSPF watershed water quality model parameters so that the timeseries of EC loads and concentrations at the inlet of the bioswale were as consistent with the input to SUSTAINOPT as possible.
3. Calibration of the HSPF RCHRES/BMP model parameters so that the HPSF-generated timeseries of EC loads and concentrations at the outfall of the BMP were as consistent with the SUSTAINOPT output as possible. At this step, in order to compare the results of the HSPF RCHRES/BMP simulation and the SUSTAINOPT simulation on the same basis, the same SUSTAINOPT input flows and EC loads were used as inputs to the HSPF RCHRES/BMP (instead of the flows and loads generated by HSPF from the drainage area).
4. As an additional calibration step, the flows and EC loads generated by HSPF from the drainage area were used as inputs to the HSPF RCHRES/BMP. The results were compared against the SUSTAINOPT output and those from Step 3 above. No adjustment to HSPF model parameters were made at this step.

The following sections provide a detailed discussion of these major calibration steps.

Calibration for Flow Hydrograph

The first step in the site-scale HSPF model calibration process was the calibration of the HSPF hydrologic parameters so that the flow hydrographs generated by HSPF at the inlet of the bioswale BMP were as consistent with the GSSHA results as possible. As listed in Table B7.1 of the QAPP, the criteria for hydrology calibration, i.e. acceptable differences between the hydrographs generated by GSSHA and HSPF, include the following:

- Error in storm volume: 15%

- Error in storm peak: 15%
- Hydrographs to be similar.

An investigation into the GSSHA modeling results found that most runoff were generated from the impervious surface of the drainage area. Therefore, HSPF model parameters associated with pervious surface (PERLND in HSPF) were found to be insensitive in the calibration process, i.e. changing these PERLND parameters have little effect on the resulting hydrograph. As a result, the original subbasin-scale HSPF model parameters for PERLND hydrology stayed unchanged in the site-scale HSPF model.

The hydrologic parameters for the impervious area (IMPLND in HSPF) and the values adopted after the calibration process are listed in Table IV-1, together with the typical and possible ranges of each parameter obtained from the BASINS Technical Note 6 (EPA, 2000). The values adopted are at the limits of the possible range that yielded the best match between the HSPF and GSSHA modeled hydrographs.

Table IV-1 HSPF IMPLND Model Parameters for Hydrology

HSPF Parameter	Description	Units	Typical Range		Possible Range		Values Adopted
			Min	Max	Min	Max	
LSUR	Length of overland flow	feet	50.0	150.0	50.0	250.0	250.0
SLSUR	Slope of overland flow plane	ft/ft	0.010	0.050	0.001	0.150	0.001
NSUR	Manning's n for overland flow	none	0.030	0.100	0.010	0.150	0.150
RETSC	Retention storage capacity	inches	0.030	0.100	0.010	0.300	0.300

The comparison between the GSSHA and site-scale HSPF model results are listed in Table IV-2. The difference in total runoff volume is 13.8%, which meets the 15% criterion. The peak flows are almost the same. The shape of the hydrographs are also similar, as shown in Exhibit IV-1, except for a 2-hour difference in the time of peak flow. This difference is due to the 2D GSSHA model involving more land surface routing resulting in longer time of concentration, while HSPF generates faster runoff response with the lack of detailed 2D effects. With BMP performance dominated by total runoff volume and peak flow through the BMP, this small difference in time to peak is not expected to affect BMP evaluation results. Overall, the results indicate a successful hydrologic calibration.

Table IV-2 Comparison between GSSHA and HSPF Hydrology Results

Variables	Units	GSSHA	Site-Scale HSPF	Difference
Runoff Volume	ac-ft	0.928	1.056	13.79%
Peak flow	cfs	1.520	1.510	0.66%

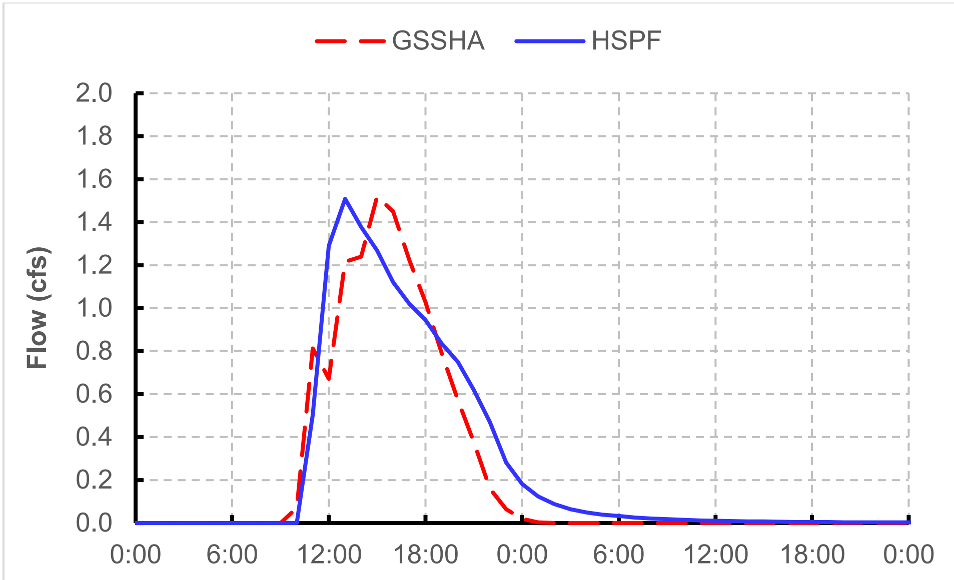


Exhibit IV-1 GSSHA and HSPF Flow Hydrographs to Bioswale

Calibration of Drainage Area Load Calculation

Following the hydrologic calibration, the next step was the calibration of the HSPF model water quality parameters so that the EC load and concentration at the inlet of the bioswale could be consistent with the SUSTAINOPT input. As listed in Table B7.2 of the QAPP, the criteria for bacteria calibration, i.e. difference between site-scale HSPF and SUSTAINOPT results, include the following:

- Error in bacteria concentrations:
  - Very Good, if <15%,
  - Good, if between 15% and 25%, and
  - Fair, if between 25% and 35%.
- The timeseries plots should be similar.

While the criteria were intended for comparing average concentrations over a substantial period of simulation, the criteria were adopted to evaluate the comparison of total EC bacteria load, peak EC concentration, and flow-weighted geometric mean (GM) EC concentration.

Because the runoff was found to be mostly from the impervious area, the EC load was also found to be mainly from the impervious area. As a result, the HSPF PERLND parameters for EC simulation were found insensitive during the calibration effort and the parameters were kept the same as in the original subbasin-scale model. The HSPF IMPLND parameters for EC simulation and the values adopted after the calibration process are listed in Table V-1 where

- SQO is the initial storage of the constituent.
- ACQOP is the rate of accumulation of the constituent.
- SQOLIM is the maximum storage of the constituent.
- WSQOP is the rate of surface runoff which will remove 90 percent of stored constituent per hour.

Table V-1 HSPF IMPLND Model Parameters and Adopted Values for EC Calibration

Landuse	SQO (10^6/ac)	ACQOP (10^6/ac-day)	SQOLIM (10^6/ac)	WSQOP (in/hr)
Residential High	0.050	12,800	89,600	1.0
Commercial	0.050	6,400	44,800	1.0
Transportation	0.050	6,400	44,800	1.0

Table V-2 lists the comparison between the calibrated site-scale HSPF model results and the SUSTAINOPT input values. Both the total EC load and peak EC concentration comparisons are "very good" and the flow-weighted GM EC comparison is "good/fair" per the calibration criteria. Exhibit V-1 shows the EC concentration timeseries of the HSPF model and SUSTAINOPT input at the inlet of the bioswale. Overall, the results indicate a successful EC calibration at the inlet of the bioswale.

Table V-2 Comparison of EC Loads and Concentrations at Inlet of Bioswale

Variables	Units	SUSTAINOPT Input	Site-Scale HSPF	Difference	Results
Total EC load	MPN	4.06E+11	4.21E+11	3.69%	Very Good
Peak EC concentration	MPN/dL	97,710	97,532	0.18%	Very Good
Flow-weighted GM EC	MPN/dL	30,954	23,068	25.48%	Good/Fair

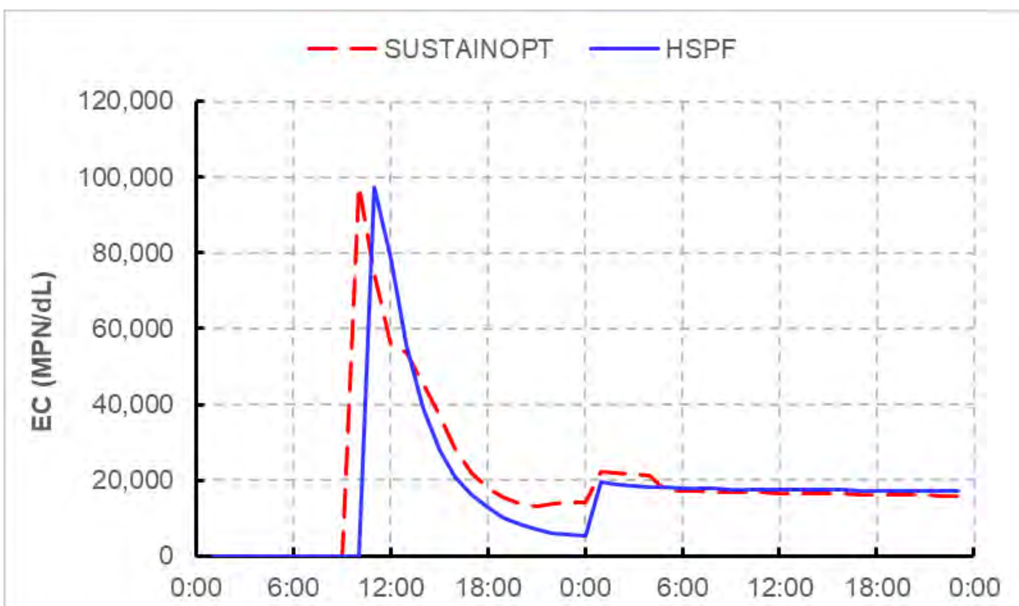


Exhibit V-1 HSPF and SUSTAINOPT EC Concentrations at Inlet of Bioswale

Calibration of RCHRES Representing Bioswale with SUSTAINOPT Input

After calibrating both flows and EC loads entering the bioswale, the next step was to conduct calibration at the BMP outfall to verify that the HPSF results were consistent with the SUSTAINOPT output. In this step, the flows and EC loads computed by HSPF from the drainage area were not used. Instead, the SUSTAINOPT input flows and loads were used as inputs to the BMP in the HSPF simulation so that the comparison would be on the same basis, i.e., based on the same inputs to the HSPF BMP and SUSTAINOPT to ensure that any differences at the BMP outfall would be attributed only to the BMP simulations by the models.

Exhibit VI-1 illustrates how the inflow to the BMP is simulated. The bioswale BMP is set up as an offline BMP, i.e. the BMP is to capture, isolate, and treat only the inflow volume from the drainage area used to size its capacity, e.g. the impervious surface from the commercial, transportation, and residential land uses, and the remaining inflow will bypass the BMP and will not be captured or treated by the BMP. A bioswale BMP is also depicted as two layers. The upper layer consists of the volume of the swale and the void space of the soil media. The lower layer is the void space of the gravel underdrain layer. The total inflow (Q_{in}) from the drainage area was split into two components—bypass flow (Q_{bypass}) and flow entering the upper layer of the bioswale (Q_{BMP}). The flow entering the upper layer infiltrates into the lower layer. Subsequently part of it infiltrates into the ground (Q_{Infil}) and the rest is the outflow from the underdrain layer (Q_{Und}), which combines with the bypass flow to become the total outflow (Q_{Out}). In the site-scale HSPF model, the upper and lower layers of the bioswale were modeled as separate reaches (RCHRES 1 and RCHRES 2), and rating relations or FTABLEs were developed to represent their volumes and outflow characteristics.

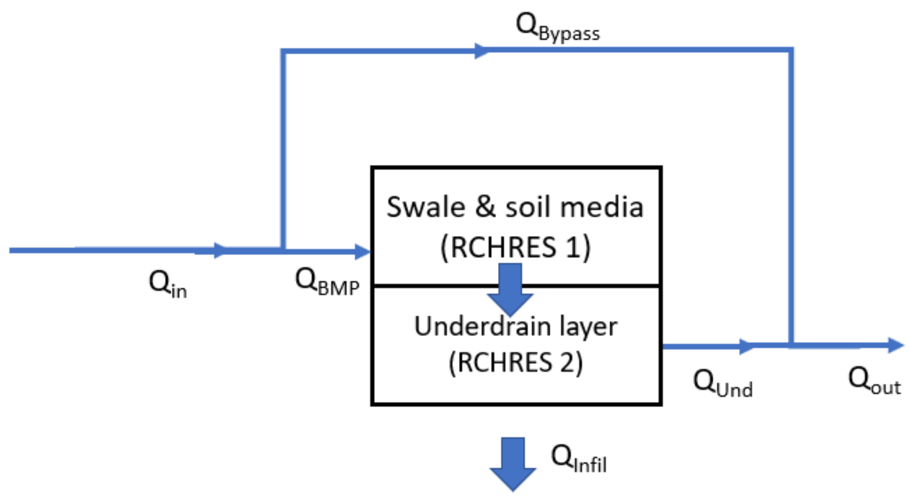


Exhibit VI-1 Illustration of an Offline Bioswale BMP

Due to the setting of capturing and isolating inflow only to its capacity, the SUSTAINOPT simulation during the proof-of-concept study resulted in almost all of the flow entering the bioswale infiltrated into the ground, i.e., Q_{Und} was almost zero. Therefore, the FTABLEs in the site-scale HSPF model were set up to reproduce this result. In this case, Q_{Out} and the associated concentration were basically the same as Q_{bypass}, and the concentration of the bypass flow was the same as the inflow. In this situation where the flow into the BMP was almost entirely infiltrated into the ground, the concentration of the outflow of the system was essentially the same as the concentration of the inflow to the system, and the load reduction achieved by the BMP is entirely from removing the EC load in the infiltrated flow. As a result, the decay process in the BMP is 100% for the flow and load that enters the BMP, but it did not have any effect on the load and concentration of the total outflow that is entirely bypass flow. Therefore, the decay coefficient of the BMP was not adjusted during the calibration, i.e., the coefficient was kept the same as in the subbasin-scale HSPF model. Table VI-1 and Exhibit VI-2 show that there is very good agreement between the SUSTAINOPT output and the HSPF model results.

Table VI-1 Comparison between SUSTAINOPT and HSPF BMP Simulation Results
(SUSTAINOPT Input Used as Input to HSPF BMP)

Variables	Units	SUSTAINOPT Output	Site-Scale HSPF	Difference	Results
Total EC load	MPN	3.17E+11	3.15E+11	0.63%	Very Good
Peak EC concentration	MPN/dL	97,895	97,908	0.01%	Very Good
Flow-weighted GM EC	MPN/dL	30,004	31,323	4.40%	Very Good

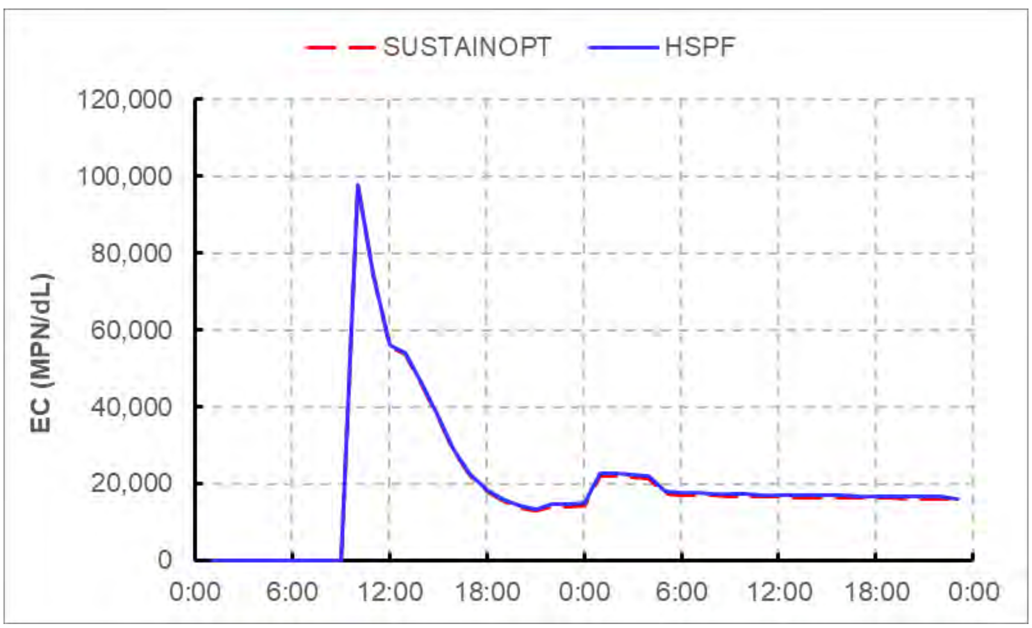


Exhibit VI-2 HSPF and SUSTAINOPT EC Concentrations at Outlet of Bioswale
(SUSTAINOPT Input Used as Input to HSPF BMP)

Calibration of RCHRES Representing Bioswale with HSPF Input

In this step, the flows and loads computed by HSPF from the drainage area were routed through the RCHRESs representing the bioswale, and the results were compared against the SUSTAINOPT output.

The purpose of this calibration step is to evaluate the difference at the BMP outfall location between the results from the 2D GSSHA modeling for drainage area coupled with SUSTAINOPT modeling for BMP versus the site-scale HSPF that includes both the drainage area and BMP simulations.

In the proof-of-concept study, the results of SUSTAINOPT simulation showed that 22.9% of the total inflow from the drainage area entered the offline bioswale BMP, and the remaining hydrograph bypassed the BMP. This 0.229 fraction was applied to the HSPF flow to split the inflow (Q_{in}) into the bypass flow (Q_{bypass}) and the flow entering the upper layer of the bioswale (Q_{BMP}), i.e. $Q_{BMP} = 0.229 \times Q_{in}$.

Because almost all of the flow into the BMP infiltrated the ground, in either the HSPF or the SUSTAINOPT simulation, the inflow and outflow concentrations are essentially the same. Therefore, as shown in Table VII-1 and Exhibit VII-1, the agreement between HSPF and SUSTAINOPT outflow loads and concentrations is very good, and the results are similar to that between HSPF and SUSTAINOPT inflow loads and concentrations (see Table V-2 and Exhibit V-1).

Table VII-1 Comparison between SUSTAINOPT and HSPF BMP Simulation Results
(HSPF Flows and Loads from Drainage Area Used as Input to HSPF BMP)

Variables	Units	SUSTAINOPT Output	Site-Scale HSPF	Difference	Results
Total EC load	MPN	3.17E+11	3.24E+11	2.21%	Very Good
Peak EC concentration	MPN/dL	97,895	97,533	0.37%	Very Good
Flow-weighted GM EC	MPN/dL	30,004	23,068	23.12%	Good

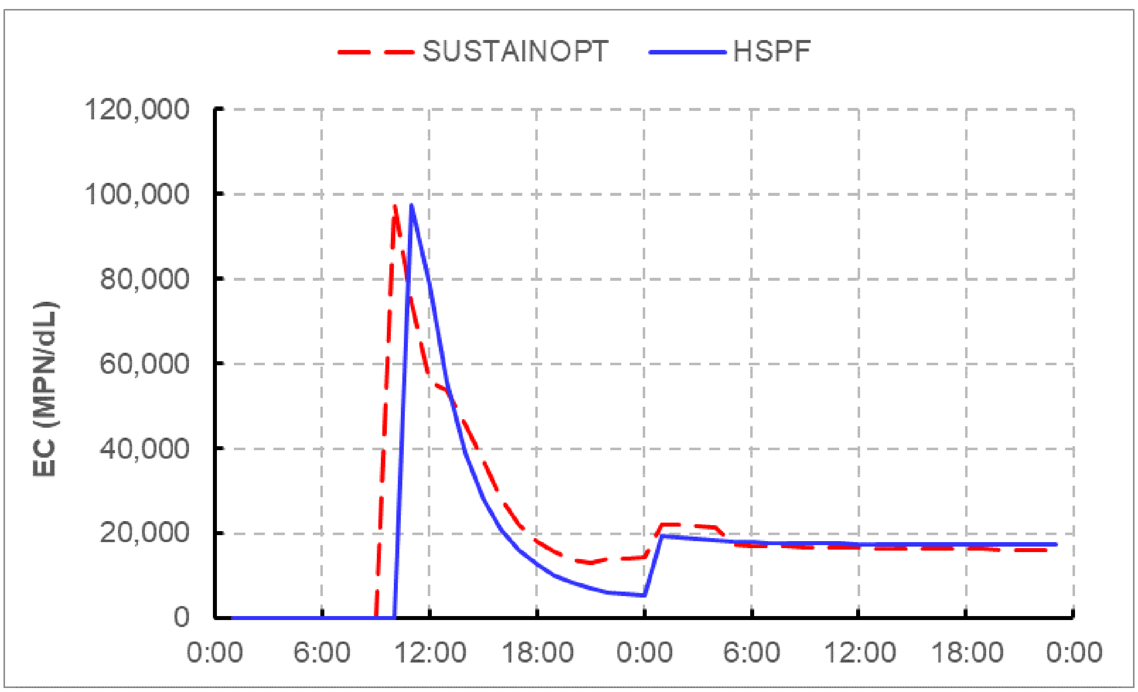


Exhibit VII-1 HSPF and SUSTAINOPT EC Concentrations at Outlet of Bioswale
(HSPF Flows and Loads from Drainage Area Used as Input to HSPF BMP)

Inline BMP

The SUSTAINOPT simulation and the site-scale HSPF simulation discussed in previous sections involves an offline BMP. In this section, the same BMP was simulated in HSPF as an inline BMP to evaluate the difference between an offline and an inline system. While this is not a calibration step, the results provide additional information to facilitate subsequent modeling efforts that may involve inline BMP systems. Exhibit VIII-1 illustrates an inline BMP where there is no bypass, i.e. all inflow is pushed through the BMP. However, in addition to the underdrain outflow (Q_{Und}), there is an overflow from the upper layer (Q_{OF}).

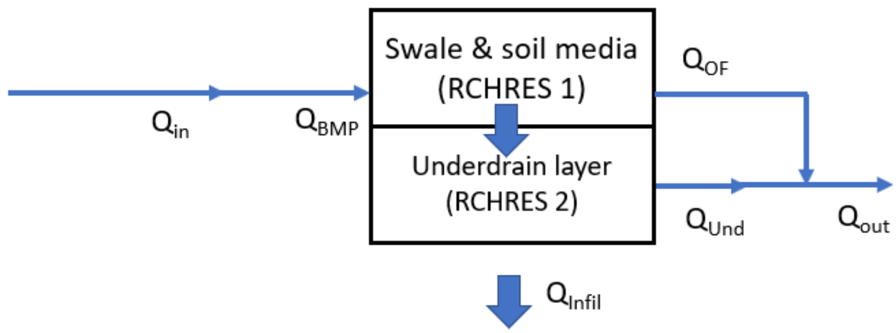


Exhibit VIII-1 Illustration of an Inline Bioswale BMP

Table VIII-1 shows the comparison of results between the inline and offline BMPs and Exhibit VIII-2 shows the EC concentrations. There are several reasons for the higher load and concentration reduction from the inline BMP. First, all flow went through an inline BMP (instead of only 0.229 of the flow being diverted, captured, and treated in the offline case), resulting in more flow being detained and infiltrated into the ground and therefore more EC load was removed. Secondly, with the entire hydrograph flowing through an inline BMP, more EC load was removed by the BMP treatment/decay process. Note that Exhibit VIII-2 shows an increase in EC concentration after Hour 0:00 of Day 2 when the diverted flow became very small (concentrations tend to go high when flow approaches zero).

Table VIII-1 Comparison between Offline and Inline HSPF BMP Simulation Results

Variables	Units	Offline BMP	Inline BMP	Difference
Total EC load	MPN	3.24E+11	1.33E+11	58.95%
Peak EC concentration	MPN/dL	97,533	31,117	68.10%
Flow-weighted GM EC	MPN/dL	23,068	14,617	36.64%

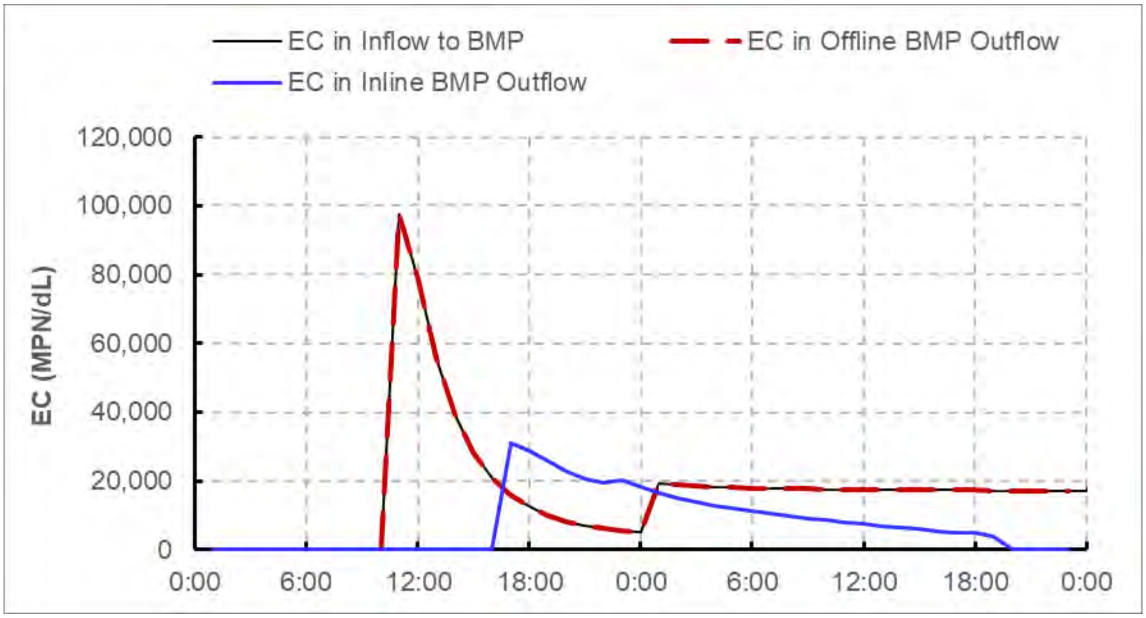


Exhibit VIII-2 EC Concentrations of Inline/Offline Bioswale Simulated by HSPF

Exhibit VIII-3 shows the flow timeseries simulated by the site-scale HSPF model for both the inline and offline bioswale scenarios. The plot shows that the total flow from the drainage area got split into a diverted flow into the offline bioswale and bypass flow components, and the bypass flow becomes the outflow from the offline BMP because the diverted flow got infiltrated completely. This resulted in the outflow EC concentrations being the same as the bypass EC concentrations.

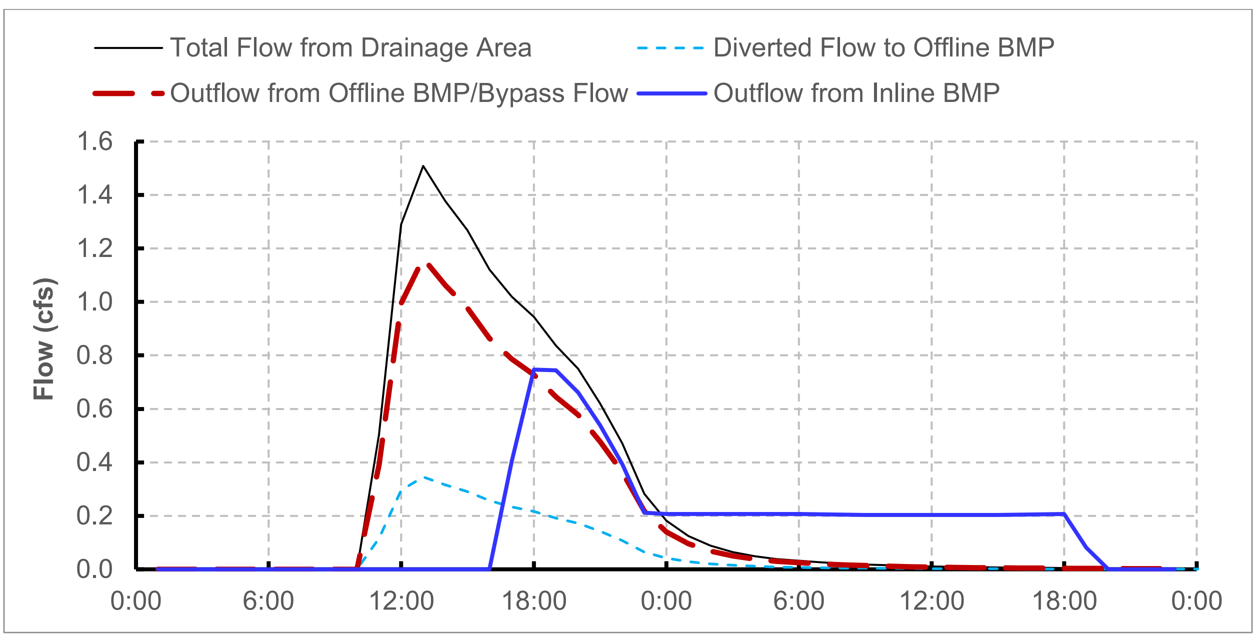


Exhibit VIII-3 Flows of Inline/Offline Bioswale Simulated by HSPF

For the inline bioswale scenario, the outflow hydrograph in Exhibit VIII-3 shows no outflow from the BMP when inflow was still filling up the BMP and part of the inflow was infiltrated. When the BMP was full (at Hour 16:00), then outflow from the inline BMP started to occur. Due to the detention effect of the

BMP, it slowly drained dry as shown by the long tail end of the hydrograph. This extended detention provided additional EC load removal.

Conclusion

Using an example bioswale BMP developed for the Brooks Creek Development Area under a 2019 proof-of-concept study, site-scale HSPF models were developed from the USAR subbasin-scale model. The models were then calibrated successfully to the hydrologic and EC results of the GSSHA and SUSTAINOPT modeling conducted under the proof-of-concept study.

The results presented in this memorandum are reasonable and expected, indicating that the site-scale HSPF models can perform well in simulating BMP flow and EC removal processes. The results also suggest that an inline BMP may provide more EC load removal than an offline BMP when the inflow is well mixed from all land uses of drainage area and when the offline BMP is designed to treat only a small portion of the total inflow.

On the other hand, if there were substantial differences among runoff EC loads from various pervious and impervious land uses and if the first flush effect were also substantial, then diverting only first flush runoff from impervious surfaces into an offline BMP would be most effective and beneficial because the most contaminated runoff volume can be isolated and treated.

As described in the QAPP, the parameters of the calibrated site-scale HSPF model was used to conduct additional modeling of the other selected BMP sites for evaluating the performance of conceptual GSI designs. When BMPs other than bioswale were selected, necessary adjustments to the models will also be made by utilizing the decay coefficient of the selected BMP types from the River Authority's BMP Database.

References

Lockwood, Andrews & Newnam, Inc. (LAN). 2019. Proof-of-Concept for Conducting Site-Scale Planning. Draft Technical Memorandum dated 08/17/2019.

San Antonio River Authority (SARA). 2019. Upper San Antonio River Watershed Protection Plan Implementation – Green Stormwater Infrastructure Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP). Revision date: 09/17/2019.

U.S. Environmental Protection Agency. 2000. BASINS Technical Note 6, Estimating Hydrology and Hydraulic Parameters for HSPF. EPA-823-R00-012.

Attachment B

Modifications to Watershed HSPF Models to Create Site-Scale Model for BMP Performance Evaluation in USAR Subbasin 70

1. Added RCHRES for the BMP simulation in the OPN SEQUENCE block. Note that:
   a. RCHRES 73 is a dummy reach, i.e. not a physical water body, to combine the outflows from the RCHRES of Bioswale N (71 and 72),
   b. RCHRES 77 is a dummy reach to combine the outflows from the RCHRES of Bioswale S (75 and 76), and
   c. RCHRES 79 is a dummy reach combining the outflows from all four BMPs.

```
*** Subbasin 70 site-scale model
*** 71 - Bioswale N, above underdrain
*** 72 - Bioswale N, underdrain
*** 73 - Bioswale N, total outflow
*** 74 - Extended detention N
*** 75 - Bioswale S, above underdrain
*** 76 - Bioswale S, underdrain
*** 77 - Bioswale S, total outflow
*** 78 - Extended detention S
*** 79 - All BMP outflow combined
      RCHRES      71
      RCHRES      72
      RCHRES      73
      RCHRES      74
      RCHRES      75
      RCHRES      76
      RCHRES      77
      RCHRES      78
      RCHRES      79
```

2. Updated IWATER parameters (hydrologic parameters for impervious area in drainage area) based on model calibration.

```
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  103  117       150    0.0281      0.10      0.20
  203  217       150    0.0219      0.10      0.20
  303  317       150    0.0138      0.10      0.20
***  403  417       150    0.0187      0.10      0.20
*** site-scale model
  403  417       250    0.0010      0.15      0.30
***
  END IWAT-PARM2
```

3. Updated IQUAL parameters (water quality parameters for impervious area in drainage area) based on model calibration.

```
*** Subbasin 70 site-scale model
***
  405          0.05        0   12800   89600        1
  406          0.05        0    6400   44800        1
  407          0.05        0    6400   44800        1
***
  410          0.05        0    4000   28000        1
  411          0.05        0    1000    7000        1
```

4. Added RCHRES 71 to 79 in the General Input under the RCHRES block.

```
RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   10   70    1    2    0    1    1    1    1    1    1    0
   71   79    1    2    0    1    1    1    0    0    0    0
   80  640    1    2    0    1    1    1    1    1    1    0
  END ACTIVITY

  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   10   70    4    4    4    4    4    4    4    4    4    4    1    9
   71   79    4    4    4    4    4    4    4    4    4    4    1    9
   80  640    4    4    4    4    4    4    4    4    4    4    1    9
  END PRINT-INFO

  BINARY-INFO
*** RCHRES  Binary Output level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   10   70    6    6    6    6    6    6    6    6    6    6    1    9
   71   79    2    2    2    2    2    2    2    2    2    2    1    9
   80  640    6    6    6    6    6    6    6    6    6    6    1    9
  END BINARY-INFO
```

```
 GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                              t-series  Engl Metr LKFG
*** x -  x                                in   out
   10      WForkOC_UpDetail        2        1     1    91    0    0   94    0
   20      WForkOC_Lower           1        1     1    91    0    0   94    0
   30    40OC_Middle               2        1     1    91    0    0   94    0
   50      OC_Middle               1        1     1    91    0    0   94    0
   60      Olmos_Crk               1        1     1    91    0    0   94    0
   70      RockCreek               1        1     1    91    0    0   94    0
*** Subbasin 70 site-scale model
   71      Bioswale_N_1            2        1     1    91    0    0   94    0
   72      Bioswale_N_2            1        1     1    91    0    0   94    0
   73      Bioswale_N_out          1        1     1    91    0    0   94    0
   74      Ex_Det_N                1        1     1    91    0    0   94    0
   75      Bioswale_S_1            2        1     1    91    0    0   94    0
   76      Bioswale_S_2            1        1     1    91    0    0   94    0
   77      Bioswale_S_out          1        1     1    91    0    0   94    0
   78      Ex_Det_S                1        1     1    91    0    0   94    0
   79      BMP_Total               1        1     1    91    0    0   94    0
***
   80    90Olmos_Crk               1        1     1    91    0    0   94    0
  100      OC_AirportTrib01        1        1     1    91    0    0   94    0
```

5. Added RCHRES 71 to 79 in the HYDR input under the RCHRES block.

```
 HYDR-PARM2
*** RCHRES FTBW FTBU        LEN     DELTH     STCOR        KS      DB50
*** x -  x                (miles)    (ft)      (ft)                 (in)
   10          0   10       1.52      56.8       3.2       0.0      0.01
   20          0   20       2.99     101.0       3.2       0.0      0.01
   30          0   30       1.66      84.1       3.2       0.0      0.01
   40          0   40       1.98      69.5       3.2       0.0      0.01
   50          0   50       3.18      57.7       3.2       0.0      0.01
   60          0   60       2.43      66.9       3.2       0.0      0.01
   70          0   70       2.74     134.0       3.2       0.0      0.01
*** Subbasin 70 site-scale model
*** Length and DELTH are dummy values, not needed for this purpose
   71          0   71        0.1       0.0       3.2       0.0      0.01
   72          0   72        0.1       0.0       3.2       0.0      0.01
   73          0   73        0.1       0.0       3.2       0.0      0.01
   74          0   74        0.1       0.0       3.2       0.0      0.01
   75          0   75        0.1       0.0       3.2       0.0      0.01
   76          0   76        0.1       0.0       3.2       0.0      0.01
   77          0   77        0.1       0.0       3.2       0.0      0.01
   78          0   78        0.1       0.0       3.2       0.0      0.01
   79          0   79        0.1       0.0       3.2       0.0      0.01
***
   80          0   80       1.68      27.4       3.2       0.0      0.01
   90          0   90       1.82      20.8       3.2       0.0      0.01
  100          0  100       2.32      92.0       3.2       0.0      0.01
```

```
  HYDR-INIT
***         Initial conditions for HYDR section
***RC HRES        VOL   CAT Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x      ac-ft       for each possible   exit  for each possible exit,ft3
   10             0.0       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   20             1.3       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   30             0.0       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   40             0.0       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   50             0.4       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   60             0.2       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   70             1.1       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
*** Subbasin 70 site-scale model
   71   79        0.0       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
***
   80             0.1       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
   90             0.5       4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0
```

6. Added RCHRES 71 to 79 in HEAT-PARM under the RCHRES block.

```
  HEAT-PARM
*** RCHRES       ELEV      ELDAT      CFSAEX      KATRAD      KCOND      KEVAP
*** x -   x      (ft)       (ft)
   10             946        137        0.95         9.5       6.12       2.24
   20             867         58        0.95         9.5       6.12       2.24
   30             996        187        0.95         9.5       6.12       2.24
   40             909        100        0.95         9.5       6.12       2.24
   50             845         36        0.95         9.5       6.12       2.24
   60             783        -26        0.95         9.5       6.12       2.24
   70    79       819         10        0.95         9.5       6.12       2.24
   80             736        -73        0.95         9.5       6.12       2.24
```

7. Added RCHRES 71 to 79 in SEDTRN input under the RCHRES block.

SAND-PM

*** RCHRES x - x		D (in)	W (in/sec)	RHO (gm/cm3)	KSAND	EXPSND
10		0.01	0.2	2.6	0.1	2.
20		0.01	0.2	2.6	0.002	1.1
30	60	0.01	0.2	2.6	0.1	2.
70	79	0.01	0.2	2.6	0.01	2.
80	280	0.01	0.2	2.6	0.1	2.
290	300	0.01	0.2	2.6	0.02	2.
310	380	0.01	0.2	2.6	0.1	2.

SILT-CLAY-PM

*** RCHRES x - x		D (in)	W (in/sec)	RHO gm/cm3	TAUCD lb/ft2	TAUCS lb/ft2	M lb/ft2.d
10		0.0006	0.004	2.3	0.00100	0.03671	0.001
20		0.0006	0.004	2.3	0.07919	0.14248	0.001
30		0.0006	0.004	2.3	0.00176	0.09353	0.001
40		0.0006	0.004	2.3	0.00100	0.28023	0.001
50		0.0006	0.004	2.3	0.00100	0.09886	0.001
60		0.0006	0.004	2.3	0.00403	0.06280	0.001
70	79	0.0006	0.004	2.3	0.19848	0.41021	0.001
80		0.0006	0.004	2.3	0.00100	0.48807	0.001
90		0.0006	0.004	2.3	0.00662	0.17349	0.001
100		0.0006	0.004	2.3	0.00304	0.26189	0.001

SILT-CLAY-PM

*** RCHRES x - x		D (in)	W (in/sec)	RHO gm/cm3	TAUCD lb/ft2	TAUCS lb/ft2	M lb/ft2.d
10		0.0001	0.00015	2.0	0.00100	0.01000	0.001
20		0.0001	0.00015	2.0	0.05914	0.11620	0.001
30		0.0001	0.00015	2.0	0.00169	0.03906	0.001
40		0.0001	0.00015	2.0	0.00100	0.05094	0.001
50		0.0001	0.00015	2.0	0.00100	0.03112	0.001
60		0.0001	0.00015	2.0	0.00325	0.03642	0.001
70	79	0.0001	0.00015	2.0	0.14069	0.32136	0.001
80		0.0001	0.00015	2.0	0.00100	0.09077	0.001
90		0.0001	0.00015	2.0	0.00397	0.07944	0.001
100		0.0001	0.00015	2.0	0.00303	0.02601	0.001

8. Updated the number of general constituents to six: HSPF can model up to a maximum of seven general constituents. There are six general constituents to model – BACT, ORGN, NH3N, NO3N, ORGP, and ORTHOP. In the original watershed model, lead and zinc are also modeled as general constituents. Their GQUAL inputs were removed so that the total number of general constituents did not exceed maximum of seven.

```
  GQ-GENDATA
*** RCHRES NGQL TPFG PHFG ROFG CDFG SDFG PYFG   LAT
*** x -  x                                      deg
   10  640    6    1    2    2    2    1    2    30
  END GQ-GENDATA
```

9. Added RCHRES 71 to 79 in GQUAL input for BACT. Note that RCHRES 73, 77, and 79 are dummy reaches used to combine the outflows from other reaches. The decay is irrelevant in these dummy reaches so a minimum decay coefficient (essentially zero) is assigned.

```
  GQ-GENDECAY
*** RCHRES     FSTDEC      THFST
*** x -   x    (/day)
   10   70        1.2        1.1
   71          1.2048        1.0
   72          1.2048        1.0
   73         0.00001        1.0
   74          1.5144        1.0
   75          1.2048        1.0
   76          1.2048        1.0
   77         0.00001        1.0
   78          1.5144        1.0
   79         0.00001        1.0
   80  640        1.2        1.1
  END GQ-GENDECAY
```

10. Added GQUAL inputs for ORGN, NH3N, NO3N, ORGP, and ORTHOP.

```
*** GQUAL 2 is ORGN
  GQ-QALDATA
*** RCHRES                GQID       DQAL    CONCID       CONV      QTYID
*** x -  x                         concid
   10  640ORGN                          0      mg/L     16052         lb
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
   10   70    0    0    0    0    0    0    0
   71   79    0    0    0    0    0    1    0
   80  640    0    0    0    0    0    0    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
   71         0.2064       1.0
   72         0.2064       1.0
   73        0.00001       1.0
   74         0.0216       1.0
   75         0.2064       1.0
   76         0.2064       1.0
   77        0.00001       1.0
   78         0.0216       1.0
   79        0.00001       1.0
  END GQ-GENDECAY

*** GQUAL 3 is NH3N
  GQ-QALDATA
*** RCHRES                GQID       DQAL    CONCID       CONV      QTYID
*** x -  x                         concid
   10  640NH3N                          0      mg/L     16052         lb
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
   10   70    0    0    0    0    0    0    0
   71   79    0    0    0    0    0    1    0
   80  640    0    0    0    0    0    0    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
   71         0.9792       1.0
   72         0.9792       1.0
   73        0.00001       1.0
   74         0.2616       1.0
   75         0.9792       1.0
   76         0.9792       1.0
   77        0.00001       1.0
   78         0.2616       1.0
   79        0.00001       1.0
  END GQ-GENDECAY
```

```
*** GQUAL 4 is NO3N
  GQ-QALDATA
*** RCHRES                 GQID       DQAL    CONCID       CONV      QTYID
*** x -  x                          concid
   10  640NO3N                           0      mg/L     16052         lb
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
   10   70    0    0    0    0    0    0    0
   71   79    0    0    0    0    0    1    0
   80  640    0    0    0    0    0    0    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
   71          0.7128       1.0
   72          0.7128       1.0
   73         0.00001       1.0
   74          0.2640       1.0
   75          0.7128       1.0
   76          0.7128       1.0
   77         0.00001       1.0
   78          0.2640       1.0
   79         0.00001       1.0
  END GQ-GENDECAY
```

```
*** GQUAL 5 is ORGP
  GQ-QALDATA
*** RCHRES                 GQID       DQAL    CONCID       CONV      QTYID
*** x -  x                          concid
   10  640ORGP                           0      mg/L     16052         lb
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
   10   70    0    0    0    0    0    0    0
   71   79    0    0    0    0    0    1    0
   80  640    0    0    0    0    0    0    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
   71            0.24       1.0
   72            0.24       1.0
   73         0.00001       1.0
   74          1.0152       1.0
   75            0.24       1.0
   76            0.24       1.0
   77         0.00001       1.0
   78          1.0152       1.0
   79         0.00001       1.0
  END GQ-GENDECAY
```

```
*** GQUAL 6 is ORTHOP
  GQ-QALDATA
*** RCHRES                GQID       DQAL    CONCID      CONV     QTYID
*** x -  x                         concid
   10  640ORTHOP                        0      mg/L     16052        lb
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
   10   70    0    0    0    0    0    0    0
   71   79    0    0    0    0    0    1    0
   80  640    0    0    0    0    0    0    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
   71           0.24       1.0
   72           0.24       1.0
   73        0.00001       1.0
   74         1.0152       1.0
   75           0.24       1.0
   76           0.24       1.0
   77        0.00001       1.0
   78         1.0152       1.0
   79        0.00001       1.0
  END GQ-GENDECAY
```

11. Added FTABLEs for RCHRES 71 to 79. Only FTABLE for RCHRES 71 shown below as an example.

```
*** Subbasin 70 site-scale model

  FTABLE     71
 rows cols                               ***
   17    5
     depth      area    volume     infil   outflow  ***
      0.00    0.0230    0.0000    0.0347    0.0000
      0.25    0.0230    0.0020    0.0347    0.0000
      0.50    0.0230    0.0040    0.0347    0.0000
      0.75    0.0230    0.0060    0.0347    0.0000
      1.00    0.0230    0.0080    0.0347    0.0000
      1.25    0.0230    0.0100    0.0347    0.0000
      1.50    0.0230    0.0121    0.0347    0.0000
      1.75    0.0230    0.0141    0.0347    0.0000
      2.00    0.0230    0.0161    0.0347    0.0000
      2.25    0.0230    0.0181    0.0347    0.0000
      2.50    0.0230    0.0201    0.0347    0.0000
      2.75    0.0230    0.0221    0.0347    0.0000
      3.00    0.0230    0.0241    0.0347    0.0000
      3.25    0.0298    0.0307    0.0347    0.0000
      3.50    0.0367    0.0390    0.0347    0.0000
      3.75    0.0436    0.0491    0.0347    0.0000
      4.00    0.0505    0.0608    0.0347    7.5000
  END FTABLE 71
```

12. The BMP site for calibration (Brooks Creek) is in Segment 4 of the watershed HSPF model. Therefore, Segment 4 parameters of PERLND and IMPLND were used in the site-scale calibrated model. However, Subbasin 70 is in Segment 1 of the watershed HSPF model, so the meteorological timeseries in the EXT SOURCES block was modified to be consistent with those of Segment 1.

```
*** Met Seg BE133
WDM2   801 PREC     ENGLZERO          SAME PERLND 401 417 EXTNL  PREC
WDM2   803 ATEM     ENGL              SAME PERLND 401 417 EXTNL  GATMP
WDM2   807 DEWP     ENGL              SAME PERLND 401 417 EXTNL  DTMPG
WDM2   804 WIND     ENGL              SAME PERLND 401 417 EXTNL  WINMOV
WDM2   805 SOLR     ENGL              SAME PERLND 401 417 EXTNL  SOLRAD
WDM2   806 PEVT     ENGL           1.3SAME PERLND 401 417 EXTNL  PETINP
***
*** Met Seg BE133
WDM2   801 PREC     ENGLZERO          SAME IMPLND 403 417 EXTNL  PREC
WDM2   803 ATEM     ENGL              SAME IMPLND 403 417 EXTNL  GATMP
WDM2   807 DEWP     ENGL              SAME IMPLND 403 417 EXTNL  DTMPG
WDM2   804 WIND     ENGL              SAME IMPLND 403 417 EXTNL  WINMOV
WDM2   805 SOLR     ENGL              SAME IMPLND 403 417 EXTNL  SOLRAD
WDM2   806 PEVT     ENGL           1.3SAME IMPLND 403 417 EXTNL  PETINP
***
```

13. Added RCHRES 71 to 79 to the EXT SOURCES block.

```
*** Subbasin 70 site-scale model
*** No rain on the BMP RCHRES
*** Met Seg BE133
WDM2   801 PREC     ENGLZERO         0SAME RCHRES  71  79 EXTNL  PREC
WDM2   803 ATEM     ENGL              SAME RCHRES  71  79 EXTNL  GATMP
WDM2   807 DEWP     ENGL              SAME RCHRES  71  79 EXTNL  DEWTMP
WDM2   804 WIND     ENGL              SAME RCHRES  71  79 EXTNL  WIND
WDM2   805 SOLR     ENGL              SAME RCHRES  71  79 EXTNL  SOLRAD
WDM2   808 CLOU     ENGL              SAME RCHRES  71  79 EXTNL  CLOUD
WDM2   806 PEVT     ENGL           1.3SAME RCHRES  71  79 EXTNL  POTEV
```

14. Specified the area of each landuse to each BMP in the SCHEMATIC block.

```
*** Subbasin 70 site-scale model
*** Bioswale N
PERLND 401                      0.0353     RCHRES  71      22
PERLND 405                      0.0843     RCHRES  71      22
IMPLND 405                      0.1566     RCHRES  71      21
PERLND 407                      0.0084     RCHRES  71      22
IMPLND 407                      0.0754     RCHRES  71      21
*** Extended detention N
PERLND 401                      0.3414     RCHRES  74      22
PERLND 405                      0.8154     RCHRES  74      22
IMPLND 405                      1.5142     RCHRES  74      21
PERLND 407                      0.0810     RCHRES  74      22
IMPLND 407                      0.7290     RCHRES  74      21
*** Bioswale S
PERLND 401                      0.0284     RCHRES  75      22
PERLND 405                      0.0679     RCHRES  75      22
IMPLND 405                      0.1261     RCHRES  75      21
PERLND 407                      0.0067     RCHRES  75      22
IMPLND 407                      0.0607     RCHRES  75      21
*** Extended detention S
PERLND 401                      1.5582     RCHRES  78      22
PERLND 405                      3.7211     RCHRES  78      22
IMPLND 405                      6.9106     RCHRES  78      21
PERLND 407                      0.3697     RCHRES  78      22
IMPLND 407                      3.3269     RCHRES  78      21
***
```

15. Added MASS-LINKs to connect surface outflows of PERLND and IMPLND to the BMPs/RCHRES.

```
*** Subbasin 70 site-scale modeling
Model 1:
  GQUAL 1 - BACT
  GQUAL 2 - ORGN
  GQUAL 3 - NH3N
  GQUAL 4 - NO3N
  GQUAL 5 - ORGP
  GQUAL 6 - ORTHOP

*** For transferring SURO and SOQUAL to RCHRES
  MASS-LINK        22
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
PERLND     PWATER SURO       0.0833333     RCHRES         INFLOW IVOL
PERLND     PQUAL  SOQUAL 1                 RCHRES         INFLOW IDQAL  1
PERLND     PQUAL  SOQUAL 3                 RCHRES         INFLOW IDQAL  2
PERLND     PQUAL  SOQUAL 4                 RCHRES         INFLOW IDQAL  3
PERLND     PQUAL  SOQUAL 5                 RCHRES         INFLOW IDQAL  4
PERLND     PQUAL  SOQUAL 6                 RCHRES         INFLOW IDQAL  5
PERLND     PQUAL  SOQUAL 7                 RCHRES         INFLOW IDQAL  6
PERLND     PWTGAS SOHT                     RCHRES         INFLOW IHEAT  1
  END MASS-LINK    22

  MASS-LINK        21
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
IMPLND     IWATER SURO         .083333     RCHRES         INFLOW IVOL
IMPLND     IQUAL  SOQUAL 1                 RCHRES         INFLOW IDQAL  1
IMPLND     IQUAL  SOQUAL 3                 RCHRES         INFLOW IDQAL  2
IMPLND     IQUAL  SOQUAL 4                 RCHRES         INFLOW IDQAL  3
IMPLND     IQUAL  SOQUAL 5                 RCHRES         INFLOW IDQAL  4
IMPLND     IQUAL  SOQUAL 6                 RCHRES         INFLOW IDQAL  5
IMPLND     IQUAL  SOQUAL 7                 RCHRES         INFLOW IDQAL  6
IMPLND     IWTGAS SOHT                     RCHRES         INFLOW IHEAT  1
  END MASS-LINK    21
```

Attachment C
Development of BMP Ranking Matrix

Introduction

Under the Upper San Antonio River (USAR) Watershed Protection Plan Implementation – Green Stormwater Infrastructure (GSI) Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP) project, potential sites were identified for the development of Best Management Practices (BMP). The selected BMP will be modeled to evaluate their performance in reducing stormwater runoff and improving water quality (WQ) with focus on reducing *E. coli* (EC) bacteria. The project team includes the Texas Commission on Environmental Quality (TCEQ), the San Antonio River Authority (River Authority), and Lockwood, Andrews & Newnam, Inc. (LAN).

Per the QAPP scope, one BMP site per subbasin was selected for modeling and BMP performance evaluation. Within each of the eight subbasins, the River Authority conducted GIS operation and site evaluation to identify several potential BMP sites. To assist with the selection of BMP site most suitable for modeling and performance evaluation, LAN developed a BMP ranking matrix using MS Excel. This ranking matrix is the first of its kind in San Antonio and it greatly helped with evaluation and selection of BMP sites within a subbasin. This attachment provides a summary of the factors considered and the scoring involved in the BMP ranking process. Exhibit I-1 shows portions of the developed BMP Ranking Matrix, indicating the complexity of the matrix.

The River Authority's BMP Ranking Matrix

The developed BMP ranking matrix is to assist the evaluation of potential BMP sites by assigning scores to key factors such as drainage area, land uses, BMP footprint area, receiving water, BMP types, shading, Location of BMP site within a subbasin, Hydrologic Soil Group, Area in floodplain X and AE zones, etc. These key factors were selected based on the River Authority and LAN's experience in the development of BMP database, water quality modeling, BMP Tool, and the Low Impact Development or LID. Screen shots of an example BMP Ranking Matrix are provided to the end of this attachment, and the columns of a BMP Ranking Matrix are described below:

- **OBJECTID_1**: ArcMap object or polygon ID (provided by the River Authority).
- **HydroID**: Hydrologic ID (provided by the River Authority).
- **DA_ID**: Subbasin ID and BMP ID (provided by the River Authority), e.g. "070-01" for USAR Subbasin 070, BMP Site 01.
- **Name**: Name of a BMP site (provided by the River Authority), e.g. "ROW Along I-10", "SAHA", etc.
- **Sara's Notes**: Any note provided by the River Authority entered for a BMP site, e.g. "Right of way along interstate 10 highway."
- **DA_acres**: Drainage area to a BMP in acres.
- **Net DA**: Net drainage area to a BMP in acres, which is the **DA_acres** minus **BMP footpring Area (ac)**.

OBJECTID_1	HydroID	DA_ID	Name	Sara's Notes	DA_acres	Net DA	DA_Score	UM_11	UB_12	RD_21	RL_22	RM_23	RH_24	RMF_25	C_31	I_41	T_51	M_61	OU_71	OC_72	U_81	W_91
1	14667	070-01	ROW Along I-10	Right of way along interstate 10 highway. Area is approximately 11 acres. Most north of Upper San Antonio River Watershed. RC: Medical Center & Far North	404.9	399.0	**4.88**	0.0	0.0	3.6	0.0	0.0	34.4	29.0	241.7	0.0	94.3	0.0	0.0	0.0	0.0	1.8
2	14668	070-02	Datapoint Drive	Adjacent to Pointe North Condominiums. South west in subbasin 70. Area is approximately 1 acre. In Medical Center, MC is interested Owned by COSA	5.3	4.6	**0.06**	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.4	0.0	0.6	0.0	0.0	0.0	0.0	0.0

DA_ID	IC%	IC%_Score	Shape_Length	Shape_Area	%Res	%Com	%Ind	%Tran	%Dev	%Dev_Score	BMP footpring Area (ac)	BMPfootprint _Score	Outfall	Outfall _Score	Avai BMP Types	BMPtypes _Score	Damage Center	DC_Score	Shading	Shading_Score	Location	Location_Score	HSG	HSG_Score	Area in X Zone	Area in AE Zone	% Area in X	Floodplain_score	Overall_Score	Ranking
070-01	85.9	**2.05**	10126	1637940	17%	60%	0%	23%	100%	**1.72**	5.94	**1.66**	1	**1.11**	1	**0.48**	0	**0.00**	10.00	**1.96**	1.00	**0.63**	1.00	**1.49**	5.94	0.00	100.00%	**1.67**	**17.08**	2
070-02	89.0	**2.12**	1064	21602	6%	82%	0%	12%	100%	**1.73**	0.70	**0.19**	0	**0.00**	2	**0.95**	0	**0.00**	4.00	**0.78**	1.00	**0.63**	1.00	**1.49**	0.70	0.00	100.00%	**1.67**	**9.07**	6

Exhibit I-1 Example Portions of Developed BMP Ranking Matrix

- **DA_Score**: Drainage area score = **Net DA** x 10 / Sum(**Net DA** of all BMP sites within the same subbasin). The "x 10" is to normalize the score within the range of 0 to 10.
- **UM_11, UB_12, RD_21, RL_22, RM_23, RH_24, RMF_25, C_31, I_41, T_51, M_61, OU_71, OC_72, U_81, W_91**: Areas in acres of each land use type.
- **IC%**: Percent impervious cover calculated based on land use types and their associated impervious cover percentages.
- **IC%_Score**: Percent impervious cover score = **IC%** x 10 / Sum(**IC%** of all BMP sites within the same subbasin).
- **Shape_Length**: Length of BMP site polygon in ArcMap.
- **Shape_Area**: Area of BMP site polygon in ArcMap.
- **%Res**: Percent Residential Areas = Sum(**RD_21, RL_22, RM_23, RH_24, RMF_25**) / **DA_acres**.
- **%Com**: Percent Commercial Areas = **C_31** / **DA_acres**.
- **%Ind**: Percent Industrial Areas = **I_41** / **DA_acres**.
- **%Tran**: Percent Transportation Areas = **T_51** / **DA_acres**.
- **%Dev**: Percent Development Areas = Sum(**%Res, %Com, %Ind, %Tran**)
- **%Dev_Score**: Percent development areas score = **%Dev** x 10 / Sum(**%Dev** of all BMP sites within the same subbasin).
- **BMP footpring Area (ac)**: Area of BMP footprint in acres (provided by the River Authority).
- **BMPfootprint_Score**: BMP footprint areas score = **BMP footpring Area** x 10 / Sum(**BMP footpring Area** of all BMP sites within the same subbasin).
- **Outfall**: Number of potential outfalls from BMP footprint to receiving water bodies.
- **Outfall_Score**: Outfall score = **Outfall** x 10 / Sum(**Outfall** of all BMP sites within the same subbasin).
- **Avai BMP Types**: Number of available BMP types that may fit the BMP footprint area. This is a judgment of 1 to 5. If the available area is a large well-shaped piece of land that has much flexibility to put different types of BMP, a score of 5 may be assigned. If available land actually consists of a large number of small pieces of land, or weird shape, then a 1 or 2 score may be assigned.
- **BMPtypes_Score**: Number of available BMP types score = **Avai BMP Types** x 10 / Sum (**Avai BMP Types** of all BMP sites within the same subbasin).
- **Damage Center**: Hydrologic damage center score = 1 if the BMP site is within a damage center or 0 if not.
- **DC_Score**: Damage center score = **Damage Center** x 10 / Sum(**Damage Center** of all BMP sites within the same subbasin), or 0 if the Sum is zero.
- **Shading**: Shading of the BMP site, assigned a value of 0 to 10 by reviewing aerial and making a judgment of the shading effect. A value of 10 will be open area with no shading.
- **Shading_Score**: Shading score = **Shading** x 10 / Sum(**Shading** of all BMP sites within the same subbasin).
- **Location**: Location of BMP site within the subbasin, with a 5 if near the downstream end and a 1 if upstream.
- **Location_Score**: Location score = **Location** x 10 / Sum(**Location** of all BMP sites within the same subbasin).
- **HSG**: Hydrologic Soil Group score with a 1 if Type D, 2 if Type C, etc. If a mixture of Types C and D, etc., then a composite value can be assigned.
- **HSG_Score**: HSG score = **HSG** x 10 / Sum(**HSG** of all BMP sites within the same subbasin).

- **Area in X Zone**: Area in floodplain X zone, calculated by intersecting floodplain layer with available land area and calculating the available land at a BMP site within the X zone.
- **Area in AE Zone**: Area in floodplain AE zone, calculated by intersecting floodplain layer with available land area and calculating the available land at a BMP site within the AE zone.
- **% Area in X**: Percent of BMP site area in X zone = **Area in X Zone / BMP footpring Area**.
- **Floodplain_score**: Floodplain score = **% Area in X** x 10 / Sum(**% Area in X** of all BMP sites within the same subbasin).
- **Overall_Score**: Weighted sum of all scores.
- **Ranking**: Rank of each BMP site within a subbasin, with the BMP site with the highest **Overall_Score** ranked number 1.
- **Remarks**: Any remarks related to a BMP site and the scoring of the site.

The ranking matrix is set up so each of the scores in the matrix is multiplied by a weighing factor when calculating the "Overall_Score". The weighing factors are located in the "Weights" row with default values of 1.0, and the overall scores will automatically update accordingly. The River Authority can adjust the values higher or lower than the default 1.0 as they see fit.

As an example of scoring key factors, as shown in Exhibit II-1, Drainage area to a BMP in acres is first obtained from GIS processing. Then, a Net drainage area to a BMP in acres is calculated, which is the Drainage area minus BMP footprint Area. Next, a Drainage area score is assigned by multiplying the Net drainage area by 10 and dividing it by the sum of Net Drainage Areas of all BMP sites within the subbasin. The "multiplying by 10" is to normalize the score within the range of 0 to 10.

As another example, as shown in Exhibit II-2, Percent impervious cover is calculated based on land use types and their associated impervious cover percentages. Then, Percent impervious cover score is assigned by multiplying the Percent impervious by 10 and dividing it by the sum of Percent impervious of all BMP sites within the subbasin.

Similarly, Percent Development Areas is calculated by summing the %Residential, %Commercial, %Industrial, and %Transportation land use together. Then, the Percent Development Areas score is assigned by multiplying the Percent Development Areas by 10 and dividing it by the sum of Percent Development Areas of all BMP sites within the subbasin.

OBJECTID_1	HydroID	DA_ID	Name	DA_acres	Net DA	DA_Score
1	14667	070-01	ROW Along I-10	404.9	399.0	**4.88**
2	14668	070-02	Datapoint Drive	5.3	4.6	**0.06**
3	14669	070-03	Dr. Marths Med Elementary	312.3	301.0	**3.68**

Exhibit II-1 Assigning Drainage Area Scores for BMP Ranking

DA_ID	IC%	IC%_Score	%Res	%Com	%Ind	%Tran	%Dev	%Dev_Score
070-01	85.9	**2.05**	17%	60%	0%	23%	100%	**1.72**
070-02	89.0	**2.12**	6%	82%	0%	12%	100%	**1.73**
070-03	70.5	**1.68**	40%	36%	6%	9%	92%	**1.58**

Exhibit II-2 Assigning Percent Impervious Cover and Percent Development Scores

As shown in Exhibit II-3, BMP footprint areas score is assigned by multiplying BMP footprint areas in acres by 10 and dividing it by the sum of BMP footprint areas of all BMP sites within the subbasin. The Number of potential outfalls from BMP footprint to receiving water bodies is assigned a score in a similar way.

The Number of available BMP types that may fit a BMP footprint area is assigned a score of 1 to 5. If the available area is a large well-shaped piece of land that has much flexibility to put different types of BMP, a score of 5 may be assigned. If available land actually consists of a large number of small pieces of land, or in weird shape, then a 1 or 2 score may be assigned.

Other key factors are scored in similar manner, and the overall scores and ranking were then calculated. The developed matrix has helped the project team prioritize the BMP sites, and also provide justification for the final selection of BMP site within each subbasin. A complete image of an example Ranking Matrix is attached below.

DA_ID	BMP footpring Area (ac)	BMPfootprint _Score	Outfall	Outfall _Score	Avai BMP Types	BMPtypes _Score
070-01	5.94	**1.66**	1	**1.11**	1	**0.48**
070-02	0.70	**0.19**	0	**0.00**	2	**0.95**
070-03	11.28	**3.15**	2	**2.22**	5	**2.38**

Exhibit II-3 Assigning BMP Footprint, Outfall, and BMP Types Scores

Reference

San Antonio River Authority (SARA). 2019. Upper San Antonio River Watershed Protection Plan Implementation – Green Stormwater Infrastructure Master Plan Data Acquisition, Modeling, and Geospatial Quality Assurance Project Plan (QAPP). Revision date: 09/17/2019.

OBJECTID_1	HydroID	DA_ID	Name	Sara's Notes	DA_acres	Net DA	DA_Score	UM_11	UB_12	RD_21	RL_22	RM_23	RH_24	RMF_25	C_31	I_41	T_51	M_61	OU_71	OC_72	U_81	W_91	IC%	IC%_Score	Shape_Length	Shape_Area	%Res	%Com	%Ind	%Tran	%Dev	%Dev_Score	BMP footpring Area (ac)
1	14667	070-01	ROW Along I-10	Right of way along interstate 10 highway. Area is approximately 11 acres. Most north of Upper San Antonio River Watershed. RC: Medical Center & Far North	404.9	399.0	**4.88**	0.0	0.0	3.6	0.0	0.0	34.4	29.0	241.7	0.0	94.3	0.0	0.0	0.0	0.0	1.8	85.9	**2.05**	10126	1637940	17%	60%	0%	23%	100%	**1.72**	5.94
2	14668	070-02	Datapoint Drive	Adjacent to Pointe North Condominiums. South west in subbasin 70. Area is approximately 1 acre. In Medical Center, MC is interested Owned by COSA	5.3	4.6	**0.06**	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.4	0.0	0.6	0.0	0.0	0.0	0.0	0.0	89.0	**2.12**	1064	21602	6%	82%	0%	12%	100%	**1.73**	0.70
3	14669	070-03	Dr. Marths Med Elementary	Middle of subbasin 70. Area is approximately 11 acres. South of Fountainhead apartment complex. West of I-10. RC: Medical Center	312.3	301.0	**3.68**	6.0	15.4	15.2	8.6	3.2	0.3	98.6	111.8	20.0	28.1	3.5	0.0	0.0	0.0	1.4	70.5	**1.68**	9542	1263132	40%	36%	6%	9%	92%	**1.58**	11.28
4	14670	070-04	Denman Estate Park	Other places in proximity: Pavilion Gwang-Ju, FEAST Homeschool Resource Center. Area is approximately 7 acres. Area surrounding body of water. RC: Medical Center COSA Bond Project - Denman Estate Park	25.4	14.8	**0.18**	0.0	0.0	16.0	0.5	0.0	0.0	3.4	1.4	0.0	2.6	0.0	0.0	0.0	0.0	1.4	34.1	**0.81**	2446	102680	78%	6%	0%	10%	95%	**1.64**	10.55
5	14671	070-05	Colonial Hills Elementary	East of High Residential area. South of Lantana Apartments. Area is approximately 4 acres. RC: Far North, near a damage center - flooding source is rock creek.	62.9	58.2	**0.71**	0.0	0.0	0.0	0.0	7.9	24.1	0.4	4.6	16.5	9.3	0.0	0.0	0.0	0.0	0.0	69.1	**1.65**	4070	254274	52%	7%	26%	15%	100%	**1.73**	4.66
6	14672	070-06	Windsor Park	South of CPS Energy building, lots of pavement. West of railroad tracks. Area is approximately 3 acres. RC: North Central Damage Center - flooding source is rock creek	43.1	40.4	**0.49**	2.4	0.0	0.0	0.0	0.0	21.5	0.0	8.8	0.0	9.6	0.0	0.9	0.0	0.0	0.0	70.7	**1.69**	4002	174272	50%	20%	0%	22%	92%	**1.60**	2.67
1	3986	150-01	Howard Early Childhood Center	5.70 acres Off of Broadway, within Near Northeast RC. North part of Subbasin 150. Surrounded by residential area	26.7	20.9	**0.71**	0.0	0.0	0.0	0.0	0.0	6.6	4.2	2.4	10.0	3.5	0.0	0.0	0.0	0.0	0.0	74.7	**2.09**	2746	107940	41%	9%	37%	13%	100%	**2.00**	5.81
2	3987	150-02	Alamo Heights Junior School	3.41 acres RC: Far Northeast Off of nacogdoches	21.4	18.0	**0.61**	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	14.8	1.7	0.0	0.0	0.0	0.0	0.0	71.8	**2.01**	1728	86603	23%	0%	69%	8%	100%	**2.00**	3.42
3	3988	150-03	Scates Park	0.56 acres DC SA23, flooding source new braunfels, austin Hwy, broadway.	6.8	6.2	**0.21**	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	71.5	**2.00**	1332	27306	74%	0%	0%	26%	100%	**2.00**	0.56
4	3989	150-04	Terrell Hills City Hall	0.4 acres City of Terrell Hills ownership	241.3	240.7	**8.18**	0.0	0.0	0.0	0.0	0.0	194.9	0.0	1.2	0.0	45.2	0.0	0.0	0.0	0.0	0.0	69.8	**1.96**	7918	976005	81%	1%	0%	19%	100%	**2.00**	0.60
5	3990	150-05	ROW	0.8 acres Residential area	9.4	8.6	**0.29**	0.0	0.0	0.0	0.6	0.0	6.5	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	68.9	**1.93**	1514	38125	75%	0%	0%	25%	100%	**2.00**	0.81
22	14688	260-01	T L Shaley Apartments	North of Culebra Rd Surrounded by residential area Owned by SAHA COSA Channels are adjacent the property	104.0	95.1	**0.71**	0.0	0.0	0.0	0.0	79.6	0.0	8.5	0.3	0.0	15.5	0.0	0.0	0.0	0.0	0.0	49.0	**0.88**	4538	420549	85%	0%	0%	15%	100%	**1.10**	8.90
23	14689	260-02	Northside ISD	edge of the subbasin surrounded by residential area	5.8	5.1	**0.04**	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	43.0	**0.77**	1020	23394	90%	0%	0%	10%	100%	**1.10**	0.73
3	25409	260-03	Loma Park Elementary	Surrounded by residential area. DC SA07, Flooding source Zarzamora Creek Drainage channels - improved channels (restoration)	585.4	578.0	**4.33**	0.8	2.9	0.0	0.0	417.3	0.0	8.5	28.0	17.1	104.6	0.0	6.1	0.0	0.0	0.0	50.7	**0.91**	10660	2367826	73%	5%	3%	18%	98%	**1.08**	7.40
25	14691	260-04	Monterrey Park	COSA, semi within damage center SA07, flooding source Zarzamora Creek. Adjacent to COSA Drainage Channel. Surrounded by Zarzamora Creek	111.8	94.6	**0.71**	0.0	0.0	0.0	1.7	54.5	0.0	2.5	35.9	4.3	12.9	0.0	0.0	0.0	0.0	0.0	62.7	**1.12**	5466	452122	52%	32%	4%	12%	100%	**1.10**	17.21
4	25410	260-05	LBJ Elementary School	Adjacent to COSA Channel. Owned by COSA, Residential Area W Commerce Street	41.4	31.3	**0.23**	6.5	13.9	0.0	0.8	16.2	0.0	0.0	1.8	0.0	1.8	0.0	0.5	0.0	0.0	0.0	23.1	**0.41**	3354	167616	41%	4%	0%	4%	50%	**0.54**	10.12
6	25412	260-05	LBJ Elementary School	Adjacent to COSA Channel. Owned by COSA, Residential Area W Commerce Street	397.6	388.5	**2.91**	11.5	135.2	0.0	32.4	49.9	0.0	9.6	91.9	10.0	33.5	0.0	12.0	11.7	0.0	0.0	38.8	**0.70**	11356	1608422	23%	23%	3%	8%	57%	**0.63**	9.17
27	14693	260-06	Edgewood GED Testing Center	Off of Old Hwy 90 W, Surrounded by Residential Area	66.3	60.6	**0.45**	0.6	0.1	0.0	0.6	20.6	0.0	9.8	17.9	2.9	11.1	0.0	2.8	0.0	0.0	0.0	65.5	**1.17**	4168	268073	47%	27%	4%	17%	95%	**1.04**	5.67
28	14694	260-07	Acme Park	Owned by COSA. East Acme Rd, and Rosemont at Bethel Place	5.4	3.4	**0.03**	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.1	0.0	0.6	0.0	2.8	0.0	0.0	0.0	25.8	**0.46**	916	21967	34%	2%	0%	12%	49%	**0.53**	1.99
29	14695	260-08	Lucero	SAHA. Off of Acme road. Adjacent to an empty lot	23.3	21.7	**0.16**	2.9	2.5	0.0	0.0	0.0	0.0	17.3	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	58.0	**1.04**	2182	94273	74%	0%	0%	2%	77%	**0.84**	1.57
5	25411	260-09	Gus Garcia Middle School	Adjacent to COSA drainage Channel. Partially within Damage Center, Flooding source Zarzamora	22.7	13.0	**0.10**	0.0	1.4	0.0	0.0	1.6	1.9	15.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.5	**1.23**	1726	91750	85%	9%	0%	0%	94%	**1.03**	9.64
31	14697	260-10	Dartmouth	owned by COSA. within damage center, flooding source Zarzamora Creek	55.2	44.5	**0.33**	1.5	2.5	0.0	0.0	4.7	0.0	7.4	17.6	13.9	7.7	0.0	0.0	0.0	0.0	0.0	72.6	**1.30**	4326	223106	22%	32%	25%	14%	93%	**1.02**	10.67
15	14681	270-01	Woodlawn Elementary	South of a significant shopping strip. Owned by SAISD. RC: Near Northwest West of Bandera Road (421)	55.1	50.5	**1.52**	0.2	0.0	0.0	0.0	12.8	3.2	4.2	18.4	10.2	6.1	0.0	0.0	0.0	0.0	0.0	71.7	**1.06**	3664	222924	37%	33%	18%	11%	100%	**1.12**	4.62
16	14682	270-02	Chryl West Apartments	West of Bandera Road South of Woodlawn Hills Elementary School North of damage center, SA04, flooding source Apache Creek.	91.5	88.0	**2.65**	0.1	0.0	0.0	0.0	25.6	3.5	12.7	28.4	10.4	10.9	0.0	0.0	0.0	0.0	0.0	70.3	**1.04**	4674	370122	46%	31%	11%	12%	100%	**1.12**	3.47
17	14683	270-03	Woodlawn Ranch Apartments	North of damage center, SA04, flooding source Apache Creek. Adjacent to COSA channels.	103.7	101.7	**3.06**	0.1	0.0	0.0	0.0	27.8	3.5	21.7	28.4	10.4	11.9	0.0	0.0	0.0	0.0	0.0	70.2	**1.04**	4980	419541	51%	27%	10%	11%	100%	**1.12**	2.01
18	14684	270-04	Huppertz Elementary	South west of damage center SA04, flooding source Apache Creek. Surrounded by significant residential area.	10.0	6.2	**0.19**	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	7.3	2.0	0.0	0.0	0.0	0.0	0.0	73.0	**1.08**	1266	40640	7%	0%	73%	20%	100%	**1.12**	3.82
1	25407	270-05	Memorial HS	Adjacent to Apache Creek. COSA Bond project for a comprehensive branch library expansion and renovation. RC: Westside	30.1	21.9	**0.66**	0.9	0.0	0.0	0.0	8.6	0.0	0.0	7.7	7.9	4.9	0.0	0.1	0.0	0.0	0.0	67.4	**1.00**	3122	121560	29%	26%	26%	16%	97%	**1.08**	8.17
7	25413	270-05	Memorial HS	Adjacent to Apache Creek. COSA Bond project for a comprehensive branch library expansion and renovation. RC: Westside	20.4	19.6	**0.59**	0.3	0.0	0.0	0.0	0.0	0.0	0.0	5.7	12.3	2.0	0.0	0.2	0.0	0.0	0.0	77.1	**1.14**	1836	82585	0%	28%	60%	10%	98%	**1.09**	0.81

OBJECTID_1	HydroID	DA_ID	Name	Sara's Notes	DA_acres	Net DA	DA_Score	UM_11	UB_12	RD_21	RL_22	RM_23	RH_24	RMF_25	C_31	I_41	T_51	M_61	OU_71	OC_72	U_81	W_91	IC%	IC%_Score	Shape_Length	Shape_Area	%Res	%Com	%Ind	%Tran	%Dev	%Dev_Score	BMP footpring Area (ac)
2	25408	270-06	General McMullen and Dartmoutj	COSA Residential High, Adjacent to Apache Creek, Next to Jose Angel Cardenas Early Childhood Center North of Rosedale Park COSA Bond Project - general park improvements. North of DC SA21, flooding source Zarzamora Creek	31.1	25.6	**0.77**	0.0	0.0	0.0	0.0	4.8	0.0	0.0	22.8	1.4	2.2	0.0	0.0	0.0	0.0	0.0	81.2	**1.20**	2428	125916	15%	73%	4%	7%	100%	**1.12**	5.58
8	25414	270-06	General McMullen and Dartmoutj	COSA Residential High, Adjacent to Apache Creek, Next to Jose Angel Cardenas Early Childhood Center North of Rosedale Park COSA Bond Project - general park improvements. North of DC SA21, flooding source Zarzamora Creek	20.6	12.9	**0.39**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4	0.0	2.1	0.0	0.0	0.0	0.0	0.0	89.9	**1.33**	1760	83215	0%	90%	0%	10%	100%	**1.12**	7.69
21	14687	270-07	Colby Glass Elementary	Partially outside of the sub270 boundary. most north of subbasin	6.8	6.2	**0.19**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.9	0.0	0.0	0.0	0.0	0.0	74.3	**1.10**	1052	27405	1%	0%	85%	14%	100%	**1.12**	0.62
7	14673	310-01	Callaghan Rd	owned by SAWS southeast of a pocket of residential area.	9.2	8.4	**0.07**	0.0	0.0	0.0	0.2	7.4	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	46.7	**0.94**	1468	37385	83%	0%	0%	17%	100%	**1.29**	0.86
8	14674	310-02	Woodlake Drive	Parts of it owned by COSA, designated as residential medium. Surrounded by residential area. West of Fredericksburg. COSA channels running through the center of the area.	78.6	68.6	**0.56**	10.3	0.0	0.0	0.2	52.9	0.0	0.0	1.7	0.0	13.3	0.0	0.0	0.0	0.0	0.0	43.0	**0.86**	4420	317739	68%	2%	0%	17%	87%	**1.12**	9.93
9	14675	310-03	Baskin Elementary School	Elementary school owned by SAISD, residential high. Next to commercial area and surrounded by residential area. Babcock and Shadyview	53.1	49.6	**0.41**	0.0	0.0	0.0	0.0	0.0	29.5	0.8	5.3	7.5	10.1	0.0	0.0	0.0	0.0	0.0	73.4	**1.48**	2740	214651	57%	10%	14%	19%	100%	**1.29**	3.45
10	14676	310-04	Maverick Elementary School	Owned by SAISD, surrounded by residential area along Babcock Rd Near Alazan unnamed Trib	10.3	7.1	**0.06**	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	7.5	0.9	0.0	0.0	0.0	0.0	0.0	72.2	**1.45**	1194	41528	19%	0%	73%	9%	100%	**1.29**	3.17
11	14677	310-05	SAWS	SAWS owned, designated as residential high Southwest of large commercial area off of NW Loop 410.	7.9	6.2	**0.05**	0.0	0.0	0.0	0.0	0.0	6.6	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	69.1	**1.39**	1254	31959	84%	0%	0%	16%	100%	**1.29**	1.74
12	14678	310-06	Lees Creek	7.4 acres (COSA owned) 4.2 acres (owned by SAISD) Longfellow Middle School Surrounded by residential area COSA channel goes through area property.	204.9	193.2	**1.58**	0.0	0.0	0.0	11.7	9.6	138.3	0.0	0.0	11.4	33.5	0.0	0.5	0.0	0.0	0.0	65.8	**1.32**	6456	828811	78%	0%	6%	16%	100%	**1.29**	11.67
13	14679	310-07	Joe Ward Park	COSA owned. Near Damage center and Alazan Unnamed Tributary. Surrounded by residential area	20.3	18.4	**0.15**	2.4	0.0	0.0	0.0	0.0	12.5	1.2	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	63.1	**1.27**	2368	82101	67%	0%	0%	21%	88%	**1.14**	1.91
14	14680	310-08	Babcock Rd	Portion of it is designated as Open Space Easements. Other is transportation. COSA channels goes through area property.	879.2	871.0	**7.12**	14.6	0.0	1.2	8.3	274.3	197.4	54.9	129.7	7.5	183.9	0.0	7.5	0.0	0.0	0.0	64.1	**1.29**	13822	3556228	61%	15%	1%	21%	97%	**1.26**	8.21
32	14698	330-01	Pin Oak II Apartment	East of Fredericksburg Rd. Surrounded by residential area and commercial area. Large Parking lot south of site selection. COSA channels north of site selection.	8.2	6.7	**0.03**	0.0	0.0	0.0	0.0	0.0	0.0	2.4	4.6	0.0	1.2	0.0	0.0	0.0	0.0	0.0	85.6	**1.95**	1244	33322	29%	56%	0%	15%	100%	**1.87**	1.52
33	14699	330-02	ROW I-10 East	Adjacent to large interstate and surrounded by commercial and residential area. COSA channel and East Woodlawn Ditch going through site selections.	748.2	746.4	**3.75**	30.9	0.0	16.7	7.7	61.6	63.3	141.6	241.0	10.3	159.1	0.0	14.6	0.0	0.0	1.5	72.5	**1.65**	15618	3026422	39%	32%	1%	21%	94%	**1.75**	1.85
34	14700	330-03	ROW I-10 West	Adjacent to large interstate and surrounded by commercial area. COSA channels and East woodlawn ditch going through site selection.	103.2	101.6	**0.51**	0.0	0.0	0.0	0.0	0.0	0.0	6.8	80.1	0.0	14.4	0.0	1.9	0.0	0.0	0.0	87.4	**1.99**	4960	417253	7%	78%	0%	14%	98%	**1.84**	1.55
35	14701	330-04	Spencer Ln	South of I-10 and adjacent to COSA Channel and East woodlawn ditch	13.7	9.6	**0.05**	6.0	0.0	0.0	0.0	0.0	1.1	2.9	2.3	0.0	1.4	0.0	0.0	0.0	0.0	0.0	45.4	**1.04**	1442	55355	30%	17%	0%	10%	56%	**1.05**	4.11
36	14702	330-05	Old Spanish Walking Trails	Walking trails located here. Adjacent to fredericksburg. East woodlawn ditch laced within area. large amount of commercial and residential area surrounding site selection. COSA channels nearby too.	1064.1	1036.6	**5.21**	63.7	0.0	16.7	7.7	65.9	75.3	167.1	416.2	10.3	219.5	0.0	20.2	0.0	0.0	1.5	73.6	**1.68**	20130	4304283	31%	39%	1%	21%	92%	**1.72**	27.50
37	14703	330-06	Fredericksberg	Surrounded by commercial and residential area. Adjacent to East woodlawn ditch and COSA channels.	94.4	90.1	**0.45**	0.0	0.0	0.0	0.0	0.0	31.8	8.8	25.5	6.7	16.2	0.0	5.5	0.0	0.0	0.0	73.7	**1.68**	5392	381792	43%	27%	7%	17%	94%	**1.76**	4.32
1	1756	420-01	Villa Tranchese Apartments	Between North Flores and San Pedro. Surrounded by residential and commercial area.	10.2	9.0	**0.39**	0.0	0.0	0.0	0.0	0.0	0.9	0.0	6.6	0.0	2.7	0.0	0.0	0.0	0.0	0.0	87.8	**0.96**	1450	41141	9%	65%	0%	26%	100%	**0.93**	1.20
2	1757	420-02	The Advanced Learning Academy	Between North Flores and San Pedro. Surrounded by residential and commercial area.	7.8	7.0	**0.30**	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	4.5	1.2	0.0	0.0	0.0	0.0	0.0	73.1	**0.80**	1050	31354	26%	0%	59%	16%	100%	**0.93**	0.77
9	25416	420-03	SAISD	Right off of 35. Adjacent to San Pedro Creek. Also in the area: Columbus Park, San Francesco Di Paolo Church, Soap Works 2	24.9	20.4	**0.87**	0.0	0.1	0.0	0.7	0.0	0.0	0.0	7.3	6.6	10.2	0.0	0.0	0.0	0.0	0.0	83.0	**0.91**	2474	100518	3%	29%	26%	41%	100%	**0.93**	4.50
4	1759	420-04	San Pedro Creek	COSA owner, Right off of 35. Adjacent to San Pedro Creek. Also in the area: Columbus Park, San Francesco Di Paolo Church, Soap Works 2	18.9	16.5	**0.71**	0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.7	0.0	10.2	0.0	0.5	0.0	0.0	0.0	85.7	**0.94**	2112	76561	13%	30%	0%	54%	97%	**0.91**	2.39
5	1760	420-05	SAISD	Right off of 35. Adjacent to San Pedro Creek. Also in the area: Columbus Park, San Francesco Di Paolo Church, Soap Works 2	5.8	3.7	**0.16**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0	89.6	**0.98**	828	23551	0%	96%	0%	4%	100%	**0.93**	2.16
6	1761	420-06	Milam Park	Adjacent to Santa Rosa Hospital and a lot of commercial activity.	55.7	52.4	**2.25**	0.0	0.0	0.0	0.0	0.0	0.0	11.4	27.0	0.0	17.4	0.0	0.0	0.0	0.0	0.0	86.9	**0.95**	4290	225478	20%	48%	0%	31%	100%	**0.93**	3.38
7	1762	420-07	UTSA	West of 35 and I-10	88.4	80.3	**3.45**	1.6	0.0	0.0	0.0	0.0	0.0	0.0	53.5	2.6	30.7	0.0	0.0	0.0	0.0	0.0	87.9	**0.96**	6782	357716	0%	61%	3%	35%	98%	**0.92**	8.13
8	1763	420-08	Commanders House	Surrounded by commercial activity	2.7	1.8	**0.08**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	90.0	**0.98**	614	10837	0%	96%	0%	4%	100%	**0.93**	0.91
9	1764	420-09	SAHA	Adjacent to apache and san pedro creek. COSA drainage channels nearby.	7.0	5.5	**0.24**	0.0	1.1	0.0	0.0	0.0	0.0	0.0	3.6	0.0	1.8	0.0	0.6	0.0	0.0	0.0	69.0	**0.76**	1092	28471	0%	51%	0%	25%	77%	**0.72**	1.50
10	1765	420-10	Martin St.	Corner of Martin and 35 Adjacent to residential and commercial area.	6.0	5.2	**0.22**	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.1	0.0	1.7	0.0	0.0	0.0	0.0	0.0	79.4	**0.87**	1118	24075	71%	1%	0%	28%	100%	**0.93**	0.72
11	1766	420-11	N Frio	East of N frio, surrounded by residential and commercial area.	32.8	31.1	**1.34**	0.0	0.0	0.0	0.0	5.3	0.0	0.0	18.6	0.0	9.0	0.0	0.0	0.0	0.0	0.0	81.7	**0.89**	2608	132867	16%	57%	0%	27%	100%	**0.93**	1.71
Weights							1																	1								1	

DA_ID	BMPfootprint_Score	Outfall	Outfall_Score	Avai BMP Types	BMPtypes_Score	Damage Center	DC_Score	Shading	Shading_Score	Location	Location_Score	HSG	HSG_Score	Area in X Zone	Area in AE Zone	% Area in X	Floodplain_score	Overall_Score	Ranking	Remarks
070-01	1.66	1	1.11	1	0.48	0	0.00	10.00	1.96	1.00	0.63	1.00	1.49	5.94	0.00	100.00%	1.67	17.08	2	Linear strips of land along roadway. Limited to swale type BMP. Actual drainage areas of individual strips much smaller. No obvious outfall location, need to check drainage system of I-10.
070-02	0.19	0	0.00	2	0.95	0	0.00	4.00	0.78	1.00	0.63	1.00	1.49	0.70	0.00	100.00%	1.67	9.07	6	Small drainage area and lack possible outfall location.
070-03	3.15	2	2.22	5	2.38	0	0.00	9.00	1.76	3.00	1.88	1.70	2.54	11.28	0.00	100.00%	1.67	20.86	1	May be able to outfall to storm sewer but need closer look with more info of storm sewer.
070-04	2.95	0	0.00	5	2.38	0	0.00	8.00	1.57	1.00	0.63	1.00	1.49	10.55	0.00	100.00%	1.67	12.75	5	Drainage area mainly the site itself which is a park. Lack possible outfall location.
070-05	1.30	3	3.33	4	1.90	0	0.00	10.00	1.96	5.00	3.13	1.00	1.49	4.66	0.00	100.00%	1.67	16.06	4	Drainage channel nearby possible outfall location but need some pipe routing.
070-06	0.75	3	3.33	4	1.90	1	10.00	10.00	1.96	5.00	3.13	1.00	1.49	2.64	0.03	98.76%	1.65	16.18	3	Drainage channel nearby possible outfall location but need some pipe routing. A ditch along adjacent railroad, but seems too shallow for outfall. Damage center SA26.
150-01	5.19	1	2.00	5	2.94	0	0.00	10.00	2.38	1.00	1.11	1.00	1.67	5.81	0.00	100.00%	2.00	21.10	2	There should be a storm sewer along Nacogdochee Road (GIS data show inlets along road but no storm sewer line), but doubt site can outfall to it.
150-02	3.05	1	2.00	3	1.76	0	0.00	9.00	2.14	1.00	1.11	1.00	1.67	3.42	0.00	100.00%	2.00	17.36	3	Small drainage area. Available land polygons relatively small. There should be a storm sewer along Nacogdochee Road (GIS data show inlets along road but no storm sewer line), but doubt site can outfall to it.
150-03	0.50	0	0.00	4	2.35	0	0.00	9.00	2.14	1.00	1.11	1.00	1.67	0.56	0.00	100.00%	2.00	12.98	4	Small drainage area and lack possible outfall location.
150-04	0.54	3	6.00	2	1.18	0	0.00	4.00	0.95	5.00	5.56	2.00	3.33	0.60	0.00	100.00%	2.00	26.69	1	A ditch nearby (see Google stree view) may be a possible outfall location. Available land polygons are relatively small.
150-05	0.72	0	0.00	3	1.76	0	0.00	10.00	2.38	1.00	1.11	1.00	1.67	0.81	0.00	100.00%	2.00	12.87	5	Small drainage area and lack possible outfall location.
260-01	1.07	1	0.29	3	0.65	0	0.00	9.00	0.85	1.00	0.43	1.00	0.91	8.90	0.00	100.00%	0.94	7.45	8	IC 49%. Not sure if able to divert flow from storm sewer and outfall back. May consider if other better sites not work out.
260-02	0.09	0	0.00	3	0.65	0	0.00	9.00	0.85	1.00	0.43	1.00	0.91	0.73	0.00	100.00%	0.94	5.39	10	Small drainage area. Relatively low IC. Lack possible outfall location.
260-03	0.89	5	1.47	4	0.87	1	2.50	9.00	0.85	3.00	1.30	1.00	0.91	7.17	0.22	96.96%	0.92	12.60	1	May divert flow from 8x7, treat, and discharge to nearby channel. Large drainage area, need large splitter box. Damage center SA07.
260-04	2.07	5	1.47	5	1.09	1	2.50	10.00	0.94	3.00	1.30	1.00	0.91	17.11	0.10	99.41%	0.94	10.73	3	May outfall to drainage channel nearby. Damage center SA07.
260-05	1.22	5	1.47	5	1.09	0	0.00	10.00	0.94	1.00	0.43	1.00	0.91	10.11	0.01	99.87%	0.94	7.81	6	Available land on east side of channel. Drainage area a lot of undeveloped area.
260-05	1.10	5	1.47	5	1.09	0	0.00	10.00	0.94	1.00	0.43	1.00	0.91	9.17	0.01	99.94%	0.94	10.73	2	Available land on west side of channel. Drainage area a lot of undeveloped area.
260-06	0.68	1	0.29	5	1.09	0	0.00	10.00	0.94	1.00	0.43	1.00	0.91	5.67	0.00	100.00%	0.94	7.57	7	Not sure if it can outfall to storm sewer along Old US 90 W.
260-07	0.24	1	0.29	4	0.87	0	0.00	10.00	0.94	1.00	0.43	1.00	0.91	1.99	0.00	100.00%	0.94	5.26	11	Small drainage area, basically the site itself. Not sure if it can outfall to nearby storm sewer.
260-08	0.19	1	0.29	2	0.43	0	0.00	9.00	0.85	1.00	0.43	1.00	0.91	1.57	0.00	100.00%	0.94	5.71	9	Small drainage area, basically the site itself. Not sure if it can outfall to nearby storm sewer.
260-09	1.16	5	1.47	5	1.09	1	2.50	10.00	0.94	5.00	2.17	1.00	0.91	9.30	0.34	96.49%	0.91	9.31	5	Small drainage area, basically the site itself. Damage center SA07. Outfall to adjacent channel.
260-10	1.28	5	1.47	5	1.09	1	2.50	10.00	0.94	5.00	2.17	1.00	0.91	7.06	3.61	66.16%	0.62	9.44	4	May outfall to adjacent drainage channel. Damage center SA21.
270-01	1.26	3	0.97	4	1.25	0	0.00	9.00	1.23	1.00	0.48	1.00	1.11	4.62	0.00	100.00%	1.11	10.67	4	There should be a storm sewer along Bandera Road to the east (GIS data show inlets along road but no storm sewer line). May divert flow, treat, and discharge to channel to the west.
270-02	0.94	4	1.29	1	0.31	0	0.00	5.00	0.68	1.00	0.48	1.00	1.11	3.47	0.00	100.00%	1.11	10.31	6	Available land polygons are small grass areas here and there in the apartment complex. May outfall to channel nearby.
270-03	0.55	4	1.29	1	0.31	0	0.00	5.00	0.68	1.00	0.48	1.00	1.11	2.01	0.00	100.00%	1.11	10.32	5	Available land polygons are small grass areas here and there in the apartment complex. May outfall to channel nearby.
270-04	1.04	0	0.00	5	1.56	0	0.00	10.00	1.37	1.00	0.48	1.00	1.11	3.82	0.00	100.00%	1.11	8.63	8	Small drainage area, basically the site itself. Lack possible outfall location.
270-05	2.22	5	1.61	5	1.56	0	0.00	10.00	1.37	3.00	1.43	1.00	1.11	8.15	0.01	99.84%	1.11	11.87	2	Available land south of channel.
270-05	0.22	5	1.61	4	1.25	0	0.00	10.00	1.37	3.00	1.43	1.00	1.11	0.81	0.00	99.96%	1.11	9.64	7	Available land north of channel. Drainage area may be larger because of storm sewer.

Appendix D. Subtask 3.2 - GSI Prioritization and Cost Report

Subtask 3.2 – GSI Prioritization and Cost Report

Existing data and modeling tools were used to identify and model Green Stormwater Infrastructure (GSI) best management practices (BMPs) in eight high priority areas for reducing nonpoint source pollutants including *E. coli* bacteria, and nutrients. First, geospatial information systems (GIS) data was used to assess these high priority areas or subbasins in regard to soil type, land use, impervious cover, existing stormwater infrastructure, topography, aerial imagery, etc. and to delineate drainage areas of potential GSI BMP sites within them. A dataset of potential GSI implementation opportunities sites were identified for each of the eight high priority areas. The process of choosing a site from the dataset of potential sites is outlined in the Technical Memorandum for HSPF Modeling for BMP Performance Evaluation. One site in each subwatershed was chosen to model. The chosen sites were modeled with GSI BMPs identified and pollutant reduction was established for each site. Concept designs were then developed using the site GSI BMP model parameters, and cost estimates calculated for the final set of implementation sites. This report includes site-scale models, concept-level designs, and cost information for each of the potential GSI projects identified in the dataset. It also prioritizes these GSI opportunities based on stakeholder feedback.

The Concept Designs and Costs for the eight modeled sites are documented in the site pages below. The Broussard Group, Inc. dba TBG Partners (TBG) completed the concept design illustrations for seven prioritized GSI sites that are described in the Technical Memorandum for HSPF Modeling for BMP Performance Evaluation. Only conceptual level GSI site layouts and dimensions were developed. Site 70 concept design was done in-house by the San Antonio River Authority and site 560 was started in-house and completed by TBG, they were used as a model for the TBG work.

The spatial coverage of the GSI BMP footprints were provided in the memorandum to show an approximate location of the features. These areas were used to calculate the potential water quality volume managed by each based on a few additional design assumptions. Detailed stage storage-discharge tables were not calculated for bioswale and bioretention features because detailed site topography and geotechnical data for the selected sites are not yet available. The assumptions used for developing cost estimates are included in Appendix E1.

This report does not provide any assumption for the depth of water storage above the soil media and underdrain layers. The available topography was reviewed from the DEM source used for the development of the BMP model in order to estimate necessary depressions down to the surface of the soil media layer for each of the conceptual bioretentions and bioswales. These assumptions were made to allow modification of the spatial footprints of the BMPs in the BMP Performance Modeling Memorandum used to ensure that flow from streets, athletic fields, and parking lots could effectively discharge into the bioswale and bioretention features. While this may slightly reduce (smaller footprint) or increase (larger footprint) the water storage capacity of the soil media and infiltration layers of the bioretention and bioswales, the difference can be made up for by adjusting the depth of the infiltration media and/or the soil media. This was done on Subbasin 420 for the south bioretention feature to account for limited space within the curb islands. Every attempt was made to adjust the outer footprints of the features to the extent practicable to facilitate flow into the systems and provide the most flexibility for adjusting media depths to achieve the target water quality volume management and to ensure that ponding depths would not exceed 2.5 feet. Both spatial and vertical volumes and dimensions will need to be adjusted to account for presently unknown variables and constraints including detailed topography, underground utilities, and the infiltration capacity of the native soils to construct these GSI BMPs.

The priority list below is in order of level of interest in implementation based on the stakeholder feedback received and documented in the subsequent Stakeholder Report. Stakeholders' preference was based on level of interest, cost consideration, triple bottom line (TBL) benefits, multi-purpose functions, convenience, operation and maintenance, and adjacent activities with local schools.

The Brooks Development Authority site was chosen to calibrate the model. It is an early adopter of GSI outlining it in their development guide and installing GSI using River Authority Watershed Wise Rebate funding. The Brooks project discussed below was designed from BMPs used in model calibration resulting in much larger GSI best management practices (BMPs) that treat more than the required water quality volume (WQV) that other sites were designed to treat. It is listed at the bottom of the priority list due to the cost of the oversized GSI BMPs as well as maintenance concerns being in the center median.

The City's Parks and Recreation and Public Works Departments are also interested in implementing GSI on redevelopment and future projects. They looked for alignment with their priorities as well as current and future planned and bond projects. Public Works' goal is to use the River Authority's high priority/impaired subbasins map as a guide to add GSI to all projects in these areas. Meeting with the San Antonio Housing Authority revealed that they are interested in incorporating GSI BMPs in future projects if their private partners are also interested. They are willing to discuss retrofitting existing projects internally as funding is available.

The overall ranking of the projects is listed below:

Ranked #1: Site 70 – Windsor Park ranked number one because the City of San Antonio Parks and Recreation Department has this project currently planned for retrofitting. The current plan is to return an old tennis court in disrepair to native vegetation. This is a great opportunity to turn it instead into a GSI feature like the extended detention basins and bioswales modeled in this neighborhood park.

Ranked #2: Site 310 – Lee's Creek Park, with recent investment and plans may be an opportunity to work with Public Works and grant, bond, and other funding opportunities.

Ranked #3: Site 260 – Monterrey Park, may be an opportunity with the trail head bond work being planned.

Ranked #4: Site 150 – The City of San Antonio's Public Works Department ROW in Terrell Heights Community Garden. The City is interested in reviewing the community feedback, largely in support, and project details for potential implementation. Their goal is to align with the City's Water Quality Visioning Document and plan projects in the high priority subbasins, which this project is. In meeting with department director and managers to discuss opportunities they looked at the ROW opportunities relative to existing and future bond projects opportunities to add GSI BMPs.

Ranked #5: Site 270 – Rosedale Park currently has no upcoming work considered. When future work is planned GSI opportunities will be considered.

Ranked #6: Site 330 – San Antonio Housing Authority's Pin Oak II Apartments will be discussed with their Asset and Property Management Departments. SAHA is interested in implementing GSI in future funded construction projects. Due to funding allocation processes it is easier for them to build GSI into design plans at the start of a project as opposed to a retrofit project.

Ranked #7: Site 420 – San Antonio Housing Authority's Tampico Street Apartments is currently in construction and the real estate transaction is closed, so it is not possible to implement the proposed GSI BMP features at this time. It could be part of future retrofit conversations with asset and property management departments. SAHA is interested in implementing GSI in future development in coordination with their private partners and the River Authority.

Ranked #8: Site 560 – The City of San Antonio's Public Works Department ROW in the Brooks Development Authority on Sydney Brooks and City-Base Landing isn't an ideal candidate because of it being a relatively new construction project and operations and maintenance of the BMP in the median would be difficult. A separate meeting with the Brooks Development Authority, their consultants, and the landowner resulted in similar concerns with additional design and construction concerns due to it being in the center of the road. They are looking for opportunities similar to the three current San Antonio River Authority GSI/LID Rebate projects in Brooks.

Next, are the site one-pagers for each of the eight modeled sites showing details on the GSI BMPs concept design and cost assumptions.

USAR Subbasin 70: Windsor Park

City of San Antonio Parks and Recreation

GSI Description: Windsor Park's bioswales treat and convey stormwater runoff from the surrounding neighborhood into extended detention basins.

Subbasin 70 Opinion of Probable Cost:

		totals	Bioswale	$ 22,004.44	$ 102,687.38
		totals	Extended Detention	$ 50,379.00	$ 235,102.00
	Summary:	**Subtotal**	**10% Mobilization, Insurance**	**30% Contingency**	**Total**
	North Bioswale	$ 38,570.00	$ 3,857.00	$ 11,571.00	$ 53,998.00
	South Bioswale	$ 34,778.13	$ 3,477.81	$ 10,433.44	$ 48,689.38
	North Extended Detention	$ 71,183.50	$ 7,118.35	$ 21,355.05	$ 99,656.90
	South Extended Detention	$ 96,746.50	$ 9,674.65	$ 29,023.95	$ 135,445.10
totals	Bioswale	$ 73,348.13	$ 7,334.81	**Total**	**$ 337,789.38**
totals	Extended Detention	$ 167,930.00	$ 16,793.00		
	Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
	North Bioswale	$ 7,620.00	$ 15.00	$ 50,850.00	
	South Bioswale	$ 6,286.50	$ 15.00	$ 41,951.25	
	North Extended Detention	$ 1,156.00	$ 4,794.00	$ 21,862.00	
	South Extended Detention	$ 4,624.00	$ 19,176.00	$ 87,448.00	
totals	Bioswale	$ 13,906.50	$ 30.00	$ 92,801.25	
totals	Extended Detention	$ 5,780.00	$ 23,970.00	$ 109,310.00	
		$ 19,686.50	$ 24,000.00	$ 202,111.25	

Subbasin 70: Bioswales (North and South) soil media is 2 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with a porosity of 0.4. Extended Detention Basin North depth is 3.5 ft, South depth is 4 ft.

USAR Subbasin 150: Terrell Heights Community Garden

City of San Antonio Public Works

GSI Description: Terrell Heights Community Garden is in a City of San Antonio right-of-way traffic island at Larchmont Drive and Greenwich Blvd. The GSI BMP proposed would capture runoff from all three surrounding streets and treat it in a bioretention basin.

Subbasin 150 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
Bioretention	$ 199,848.00	$ 19,984.80	$ 59,954.40	$ 279,787.20
			Total	**$ 279,787.20**
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
Bioretention	$ 22,920.00	$ 35,280.00	$ 122,040.00	

Subbasin 150: Soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 260 North: Monterrey Park

City of San Antonio Parks and Recreation

GSI Description: Monterrey Park's proposed bioretention basin would treat runoff from Fortuna Street adjacent to it as well as runoff from the soccer field.

Subbasin 260 North/South Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
North Bioretention	$ 111,543.75	$ 11,154.38	$ 33,463.13	$ 156,161.25
South Bioretention	$ 571,973.38	$ 57,197.34	$ 171,592.01	$ 800,762.73
	$ 683,517.13	$ 68,351.71	**Total**	**$ 800,762.73**
			$ 205,055.14	
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
North Bioretention	$ 11,078.00	$ 17,052.00	$ 58,986.00	
South Bioretention	$ 52,763.75	$ 81,217.50	$ 280,946.25	
	$ 63,841.75	$ 98,269.50	$ 339,932.25	

Subbasin 260 (North and South): Soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 260 South: Monterrey Park

City of San Antonio Parks and Recreation

GSI Description: Monterrey Park's proposed southern bioretention basins are placed in the current parking islands and would treat runoff from Fortuna Street adjacent to it as well as runoff from the soccer field.

Subbasin 260 North/South Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
North Bioretention	$ 111,543.75	$ 11,154.38	$ 33,463.13	$ 156,161.25
South Bioretention	$ 571,973.38	$ 57,197.34	$ 171,592.01	$ 800,762.73
	$ 683,517.13	$ 68,351.71	**Total**	**$ 800,762.73**
			$ 205,055.14	
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
North Bioretention	$ 11,078.00	$ 17,052.00	$ 58,986.00	
South Bioretention	$ 52,763.75	$ 81,217.50	$ 280,946.25	
	$ 63,841.75	$ 98,269.50	$ 339,932.25	

Subbasin 260 (North and South): Soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 270: Rosedale Park

City of San Antonio Parks and Recreation

GSI Description: Rosedale Park's bioretention basin would treat stormwater runoff flowing down Ruiz Street adjacent to it.

Subbasin 270 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
Bioretention	$ 100,545.31	$ 10,054.53	$ 30,163.59	$ 140,763.44
			Total	**$ 140,763.44**
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
Bioretention	$ 6,898.92	$ 10,619.28	$ 36,734.04	

Subbasin 270: Soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 310: Lee's Creek Park

City of San Antonio Parks and Recreation

GSI Description: Lee's Creek Park, with recent investment and plans may be an opportunity to work with Public Works and grant, bond, and other funding opportunities.

Subbasin 310 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
Bioswale	$ 28,630.63	$ 2,863.06	$ 8,589.19	$ 40,082.88
Bioretention	$ 88,852.75	$ 8,885.28	$ 26,655.83	$ 124,393.85
			Total	
Maintenance Summary:	Annual Maintenance (Total Cost Per Year on Average)	Intermediate Maintenance (Once every 6 to 10 Years)	Replacement (After 20 Years of Service)	
Bioswale	$ 1,090.61	$ 1,678.74	$ 5,807.07	
Bioretention	$ 7,189.24	$ 11,066.16	$ 38,279.88	
		$ 12,744.90		

Subbasin 310: The bioswale soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with a porosity of 0.4. Length 60 ft, bottom width 5 ft, side slope 3:1, depth of swale 0.75 ft. The bioretention soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr, and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 330: Pin Oak II Apartments

San Antonio Housing Authority

GSI Description: Pin Oak II Apartments would be a retrofit treating runoff from a neighboring parking lot to the west and from most of the site’s parking lot and streets.

Subbasin 330 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
Bioswale	$ 91,615.75	$ 9,161.58	$ 27,484.73	$ 128,262.05
Bioretention	$ 108,294.10	$ 10,829.41	$ 32,488.23	$ 151,611.74
			Total	
Maintenance Summary:	Annual Maintenance (Total Cost Per Year on Average)	Intermediate Maintenance (Once every 6 to 10 Years)	Replacement (After 20 Years of Service)	
Bioswale	$ 5.73	$ 8.82	$ 30.51	
Bioretention	$ 4,051.11	$ 6,235.74	$ 21,570.57	
		$ 6,244.56		

Subbasin 330: Soil media is 3 ft deep with a porosity of 0.35 and an infiltration rate of 1.5 in/hr (south bioretention), 0.1 in/hr (north bioretention), and the underdrain layer is 1.5 ft deep with porosity of 0.4.

USAR Subbasin 420: Tampico Apartments

San Antonio Housing Authority

GSI BMP Description: Soil media is 3 ft deep for north bioretention and 4 ft deep for south bioretention so that sufficient WQV can be provided. Porosity is 0.35 and the infiltration rate is 1.5 in/hr. The underdrain layer is 1.5 ft deep with a porosity of 0.4.

Subbasin 420 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
West Bioretention	$ 75,979.50	$ 7,597.95	$ 22,793.85	$ 106,371.30
South Bioretention	$ 61,843.75	$ 6,184.38	$ 18,553.13	$ 86,581.25
	$ 137,823.25	$ 13,782.33	**Total**	**$ 86,581.25**
			$ 41,346.98	
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
West Bioretention	$ 5,875.16	$ 9,043.44	$ 31,282.92	
South Bioretention	$ 4,834.21	$ 7,441.14	$ 25,740.27	
	$ 10,709.37	$ 16,484.58	$ 57,023.19	

Subbasin 420: Soil media is 3 ft deep for north bioretention and 4 ft deep for south bioretention so that sufficient WQV can be provided. Porosity is 0.35 and the infiltration rate is 1.5 in/hr. The underdrain layer is 1.5 ft deep with a porosity of 0.4.

USAR Subbasin 560: Sydney Brooks Drive

City of San Antonio Parks and Recreation/Brooks Development Authority

GSI Description: The BMPs chosen for the Sydney Brooks Drive and City Base Landing site were used to calibrate the model by comparing the GSI modeling results to the site-scale modeling done previously using 2D GSSHA modeling. At the time, a larger BMP footprint was selected due to the use of 1.8-inch design rainfall and to maximize stormwater treatment (instead of just to treat the WQV, the BMP was sized based on available footprint). Given that this site is used for model calibration, the same BMP layout had to be used and sized for GSI modeling in order to compare to the GSSHA output. Subsequent sites were sized using the WQV.

Subbasin 560 Opinion of Probable Cost:

Summary:	Subtotal	10% Mobilization, Insurance	30% Contingency	Total
ROW Bioswales	$ 1,879,920.00	$ 187,992.00	$ 563,976.00	$ 2,631,888.00
			Total	**$ 2,631,888.00**
Maintenance Summary:	**Annual Maintenance (Total Cost Per Year on Average)**	**Intermediate Maintenance (Once every 6 to 10 Years)**	**Replacement (After 20 Years of Service)**	
ROW Bioswales	$ 34,196.64	$ 52,637.76	$ 182,083.68	

Subbasin 560: Bioswales soil media depth is 2 ft, with a porosity of 0.35 and infiltration rate is 1.5in/hr. The underdrain layer is 1.5 ft with a porosity of 0.4.

Appendix E1. GSI Master Plan Opinion of Probable Construction Cost (OPCC) Assumptions

The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

1. OPCC classified as an AACE Class 4 Estimate with an expected accuracy range of -15% - + 40%. A 30% contingency factor was utilized to formulate the OPCC.
2. The River Authority’s OPCC does not include costs associated with engineering fees, permits, surveying, etc.
3. The River Authority’s OPCC utilized a 10% factor for contractor mobilization, bond, and insurance.
4. All estimated maintenance and replacement costs utilized the unit costs provided in the San Antonio River Basin Low Impact Development Technical Design Guidance Manual.
5. All quantities for cost calculation were correlated with the report by LAN and the conceptual drawings.
6. Demo quantity referenced the amount of potential cut with a 1.15 factor to account for extra grading and excavation possibly required.
7. Geotextile fabric was assumed to line the bottom and side walls of all bioretention and bioswale basins.
8. Underdrain drainage layers were assumed to be 1.5’ for all bioretention and bioswale basins.
9. Soil media was assumed at a depth of 2’ for all bioretention and bioswale basins.
10. Porosity was calculated at 0.35 for soil media and mulch, while 0.4 was used for gravel layers.
11. The open depth of each bioretention and bioswale basin was assumed to be 9”.
12. Underdrain pipes were included for all bioretention basins and all bioswales assumed no inclusion of underdrains.
13. The 4” soil media barrier for bioretention and bioswales included 2” of washed sand over 2” of #8 choking stone.
14. PVC piping underdrain estimate include fittings and PVC glue.
15. Extended detention basins assumed hydromulching as the form of vegetation establishment. This also includes an allowance for watering the areas.
16. Reinforced concrete pipe (RCP) price includes the cost for connecting to the downstream storm drain system.
17. Restoration allowance includes the cost for SWPPP installation on-site.

Appendix E. Workshop 1: Terrell Heights Neighborhood Association (THNA) Board Meeting on February 28, 2021, on Site 150, City of San Antonio Right-Of-Way (ROW).

Michelle E. Garza

Subject:	[EXTERNAL] Invitation: THNA Check-in @ Sun Feb 28, 2021 2:30pm - 3:30pm (CST) (megarza@sariverauthority.org)
Start:	Sun 2/28/2021 2:30 PM
End:	Sun 2/28/2021 3:30 PM
Recurrence:	(none)
Meeting Status:	Accepted
Organizer:	mariverduzco74@gmail.com

External Email: Beware of links/attachments.

You have been invited to the following event.

THNA Check-in

When	Sun Feb 28, 2021 2:30pm – 3:30pm Central Time - Chicago
Joining info	Join with Google Meet meet.google.com/umi-qqze-szk
Calendar	megarza@sariverauthority.org
Who	• mariverduzco74@gmail.com - organizer • marymiles1234@gmail.com • anna.kehde@gmail.com • janetgrojean@gmail.com • katelgriffin@gmail.com • hilda@8aelectric.com • sjntemple@yahoo.com • klkimbell@yahoo.com • tysheehan@hfgtx.com • chammcjo@gmail.com • amphillipsa@hotmail.com • kiriethgrace@gmail.com • megarza@sariverauthority.org

Stakeholder Workshop Outline:

The purpose is to share the project with property owners and stakeholders (Terrell Heights Community Garden and Terrell Heights Neigborhood Association Members) to gather feedback and input on the work done to identify and model GSI/LID BMPs on public property as well as implementation potential.

- Overview of the GSI Master Plan - EPA 319 Grant Project
- Review GSI BMP opportunity in Terrell Heights Community Garden
    - Provide an overview of the site's water quality modeling, triple bottom line analysis, and concept-level designs
- Gather feedback on the desire to have the rain garden included in the neighborhood's community garden green field area.

See Appendix H for the presentation given to the Terrell Heights Neighborhood Association and Community Gardeners.

Appendix F. Terrell Heights ROW Signage

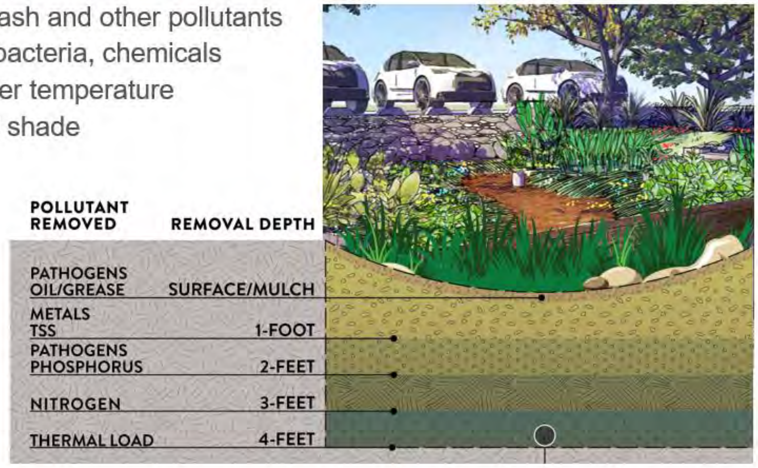
Front:


150-05
TERRELL HEIGHTS COMMUNITY GARDEN
The San Antonio River Authority is developing a Green Stormwater Infrastructure (GSI) Master Plan for the Upper San Antonio River Watershed in partnership with the US Environmental Protection Agency (US EPA) and the Texas Commission on Environmental Quality (TCEQ).
The image to the right is of the proposed GSI best management practice (BMP) in the Terrell Heights community green space.
The GSI BMP proposed for this site is a bioretention basin, or rain garden. They are designed to capture and treat stormwater, using rainwater as a resources for trees and native plants.
To provide input and view project details, please visit the Terrell Heights Community Garden Survey, by pointing your camera at the QR code below and following the link.
You can also reach out to the project manager, Michelle Garza, at megarza@sariverauthority.org, (210) 302-3265.
Thank you!
Terrell Heights Community Garden Survey
GREENWICH BLVD
LARCHMONT DRIVE
LARCHMONT DRIVE
+0.00'
-1.00'
-2.00'
-3.00'
Vegetated swale
Bioretention Basin (~11,970 SF)
Bioretention cross-section
Rainwater flows from the neighborhood, through the streets and into the bioretention basin where it is scrubbed for pollutants and/or allowed to soak into the ground. Any excess rainwater, particularly during large storm events, flows over the top edge of the bioretention basin and into the street ROW.
Character Images
100'
Committed to Safe, Clean, Enjoyable Creeks and Rivers.
1

Back:

Bioretention Basins are designed to:

- Capture floatable trash and other pollutants
- Reduce sediment, bacteria, chemicals
- Moderate stormwater temperature
- Provide habitat and shade
- Alleviate flooding



PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

SAN ANTONIO RIVER AUTHORITY

EPA United States Environmental Protection Agency

To learn more visit: sariverauthority.org/sustainability

Committed to Safe, Clean, Enjoyable Creeks and Rivers. 2

Appendix G. Terrell Heights Neighborhood Survey Link, Image, and Questions/Responses.

Terrell Heights Neighborhood Survey:

Terrell Heights Neighborhood Survey

Questions Responses 28

Terrell Heights Larchmont Island / Green Stormwater Infrastructure (GSI)

Please provide your input after reviewing the San Antonio River Authority's proposal for Green Stormwater Infrastructure (GSI) and the General Presentation for maintenance. A follow up meeting with the San Antonio River Authority will be held on April 6th at 6PM. MEETING LINK HERE: https://drive.google.com/file/d/1LfAXtHP1TOKoaobh-aEWPk7wrRv8Z5iN/view?usp=sharing.

San Antonio River Authority's Presentation for GSI Master Plan Grant Project: https://drive.google.com/file/d/1JGRsvMSkcE2myCxaranEK9FwxuMasbO5/view?usp=sharing

Here is a link to a map with other green infrastructure projects the SA River Authority has built or funded. It shows some examples that you can visit. https://www.sariverauthority.org/be-river-proud/sustainability

General presentation on maintenance for Green Stormwater Infrastructure: https://drive.google.com/file/d/12p48Ff-qu9CS0dZ1q1lsMK5FZNVdjERJ/view

Terrell Heights Neighborhood Survey Questions/Responses as of 5/14/2021:

1. Do you have concerns about the addition of a bioretention area to this green space?

No, it is a great idea
Terrific idea as long as it fits the natural aesthetic of the area.
Will water flow change to flood our streets? Will this affect the community garden?
No
No, I think it sounds like a welcome addition
Yes, really just a lot of questions. Who will be doing the ongoing maintenance stated in the presentation? Will this increase more mosquitos or flies? How will the community be able to use the

space or will it be for looks only and not be able to use for kids to play, etc? Are there examples of this in San Antonio we can go look at to see what we are signing up for?
No. I'm excited about the prospect and would like to be involved with more conversations. Many areas of the TH neighborhood would benefit during rainfall events from the building of bioswales and rain gardens instead of flashy flow events. I'd love to see bioretention be built into mini roundabouts and traffic calming and pedestrian crossings.
No. I think it is a great idea.
yes. not clear on exactly how it works and would look. we don't get much rain.
Yes
I live at 607 Greenwich Blvd, directly across from the proposed bio retention area. My concerns are 1) standing water and increase in the mosquito population 2) the native soil in this area is clay that expands when wet, how will this be dealt with? 3) aesthetics - what exactly will I be seeing when I look out my front window? 4) red-shouldered hawks currently use the green space for hunting and they perch in the existing trees; what will happen to them? 5) squirrels use the acorns from the planted oaks as a food source; what will happen to them?
Yes. Sounds like a good idea, but will there be standing water? The runoff in the street: where does it go? Will the trees remain: lots of wildlife use them now.
No, sounds like a good idea
I'm excited we would have this in our neighborhood.
I am a little concerned this will take away open space that is currently used for playing by neighborhood children. I am also concerned with maintenance once this is set up. Will this be maintained regularly?
No concerns
No, would love it to happen
Mosquitoes
Yes, a few, though it really pertain to design, which is not determined at this time. E.g. - how will output water flow and where will it flow to? Concerned this will affect my front-of-house space in the street in front of our house. This space is DIRECTLY across the street from us. Also, how will our property value and taxes be affected? Will this cause additional puddles & flooding after rain events, right around the island and in front of our house? How will it be maintained by COSA? Will it be an eyesore? Will they repave the road on Greenwich, as right now it's plagued by puddles and potholes. How long will construction last? Will it be a noise pollutant? I have a baby whose room is on the street side, so this is of concern to me in many ways.
No
Yes. Effective bioretention requires proper soil infiltration or a nearby storm sewer outfall. The nearest storm sewer in the area appears to be approximately 1800 ft West of the park along N. New Braunfels. After reviewing the SARA presentation, it seems that they intend for the storm water runoff to infiltrate. The Terrell Heights area is largely build on hard packed Houston Clay that has an extremely low (near zero) infiltration rate. Unless the SARA intends to utilize underground rainwater catchment & a pump to dry the retention area, the park will tend to hold water for extended periods of time. I also have concerns about planting, maintenance, and pest management.
No, I think it's a great idea.
My only concern is that the designated people take proper care of it over time.

No concerns.
No
Feasibility and effectiveness
How will the project be funded and what support is available in maintaining the vegetation? Is there a time frame to complete the project? Can the project be scaled down to not cover the entire perimeter of the island? Will we be able to have some educational signage placed on the island to educate the residents about how to create rain gardens in their own landscapes to manage storm-water runoff.
No

2. What do you like about the proposed project?

It is an innovative way to collect our precious rain water and conserve water.
Green, green, green.
That it is a GREEN initiative.
Beneficial
We need to be utilizing our green spaces to help the environment in a nice way
The clean look, how it helps with flood prevention, natural habitat and landscaping adds value and benefits the environment.
Excited to see forward thinking, ecoconscious ideas be brought to the neighborhood to slow the flow of water during rainfall events since this neighborhood does not have storm sewers. This is an aestheticly pleasing and beneficial change instead of adding storm sewers.
sustainability and environmental awareness.
environmentally friendly.
I think the traffic islands in Terrell Heights in general are in need of a master plan to improve them so that they are an asset to the neighborhood instead of being eyesores. I like that we are trying to think creatively, but also think this project is not what is needed at the Larchmont island
A natural (green) approach to slowing down and cleaning urban runoff. Maybe increase my property value? More diverse vegetation in the green space than currently. Maybe attract more birds and small animals. Overall I like the concept of a bio retention area.
Keeping contamination out of the water system.
added plants
Shows sustainable ways of catching water and reusing. Can be beautiful and better than just empty lot (at that end of the circle).
I like the fact that it is environmentally conscious and will help with rainwater.
Seems like it will help the space look better and also help drain water from the roads
Collection of rainwater, eco habitat, more plants on island. Enhance the education of ecology to the neighborhood. Lovely addition to the community garden on the island
The beauty of it

If it's attractive and enhances the space, then I would like that. It's hard to know what it will look like without a mock-up and real model to judge by.
Beautification and helping with drainage
If properly designed, the project would beautify a portion of the intersection that is currently just a grassy area.
The project serves a common good for the community.
I love that it's an environmentally friendly option.
I like that it’s beautifying the neighborhood and that it’s good for the environment.
Environmental love
Filtering storm water is a good thing
I support the concepts behind constructing bioretention basins on public land and adding a variety of native plants and grasses to the landscape.
Environmental love

3. What would you change if anything?

No
Nothing
I would include our neighborhood to provide a town hall meeting to discuss openly in a forum.
Nothing
Nothing
I don’t know enough about it. I think we need a neighborhood meeting from the city to neighbors surrounding the land
Add more faculties into the neighborhood in conjunction with traffic calming mini roundabouts.
Nothing
don't know enough to say.
Look at alternatives to the this BMP feature
Hopefully it will function as designed.
Don’t know enough about it to change things.
Add more shade trees and some seating, or a covered seating area
Looks like there is parking. Don’t make many places please. Then it looks commercial, and not residential.
Not information information to answer this question.
No
No
Not sure

Would love for it to be designed so that water is not flowing out in front of our house. Would also like for it to possibly be moved more towards the corner of the island, towards Eisenhauer, so it's not directly across from our house. If possible.
More butterfly friendly plants
I'd like to see a geotechnical report for the site as well as a potential for pumped discharge & rainwater harvesting. I'd like to see calculations for the drain-time of the retention basin and would prefer a drain time of 72 hours or less.
Nothing
Nothing
No.
Na
Right project, wrong place
Not sure. Will know after the community input meeting.
Na

4. Do you think this project is feasible?

Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
maybe
No
Yes
Don’t know.
Yes
Yes
Yes
Yes
Yes
Yes

I am not sure. I have read through all of the powerpoints, but hard to understand if this will be easily maintained? And how will it affect our daily life?
Yes
Project may be feasible pending further info and evaluation
Yes
Yes
Yes
Yes
No
Yes
Yes

5. Do you know of any funding sources to implement the project or help maintain it if it were constructed?

No
Terrell Heights gardners and neighborhood
no
No
No
No but we have a strong community garden presence so having a twice a year “clean up” would be doable
THNA has funding for maintenance of the existing spaces in the neighborhood and maintains them as well.
No
no
No
No
No
No
SAWS has grants sometimes, if we were a non-profit, could also apply to Lowe’s and Hone Depot for $500 a year in supplies. We do this at a lot of school campuses. I train teachers on creating gardens and sustaining them.
No
No
No right now

No
No
Terrel Heights Neighborhood Association
Not at this time
Herb sale
Local universities teaching architecture / landscape architecture might be able to volunteer student help for teaching purposes. Could larger corporations wanting to support a green story fund it in some way and be able to have their name affiliated with it?
Not at the moment.
No
If you have to ask this question, then the project is infeasible.
NPSOT for plants, City Tree Program, Alamo Area Master Naturalists, Terrell Heights CG
No

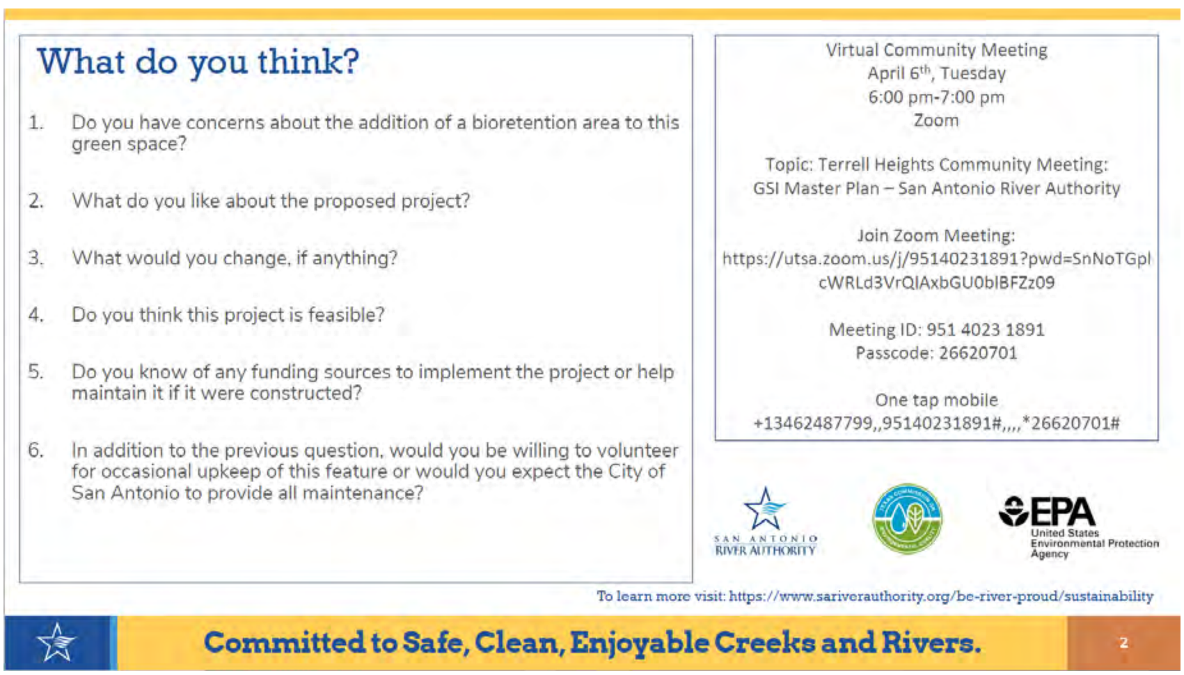
6. THNA Question: In addition to the previous question, would you be willing to volunteer for occasional upkeep of this feature or would you expect the City of San Antonio to provide all maintenance?

I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I would not be able to volunteer
Not sure but willing to help
I would be happy to volunteer once per month
I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I think the City of San Antonio should provide all maintenance
I would be happy to volunteer on occasion (3-4 times per year)
City should provide maintenance and planning. What is this going to look like in 25/50 years? But I would be willing to help.
I think the City of San Antonio should provide all maintenance
I would be able to do twice a year, but not sure about quarterly. I often teach on Saturdays when they do these gardening days.
I think the City of San Antonio should provide all maintenance

I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I would be happy to volunteer on occasion (3-4 times per year)
I think the City of San Antonio should provide all maintenance
I would be happy to volunteer once per month
I would be happy to volunteer on occasion (3-4 times per year)
I'm willing to volunteer occasionally but feel the City of SA should provide the majority of the maintenance.
I agree with community involvement (and would be happy to volunteer on occasion) but I don't think it's a proper long-term answer for upkeep and maintenance.
I would be happy to volunteer on occasion (3-4 times per year)
I would not be able to volunteer
I think the City of San Antonio should provide all maintenance
I would be happy to volunteer on occasion (3-4 times per year)
I would not be able to volunteer

Appendix H. Terrell Heights Community Meeting presentation and flyer held on April 6, 2021.

Meeting Invitation Flyer:



Meeting Presentation:

Upper San Antonio River Watershed Green Stormwater Infrastructure (GSI) Master Plan

EPA/TCEQ Clean Water Act 319(h) Grant Project
Terrell Heights

ACKNOWLAGE OF FINANCIAL SUPPORT

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

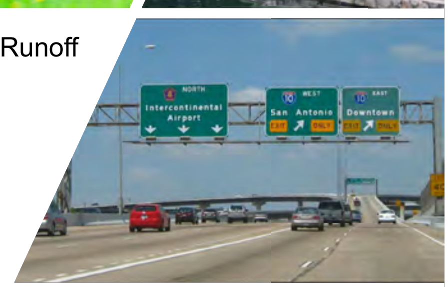
This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement 19-90204 to Texas Commission on Environmental Quality. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

"States report that nonpoint source pollution is the leading remaining cause of water quality problems."

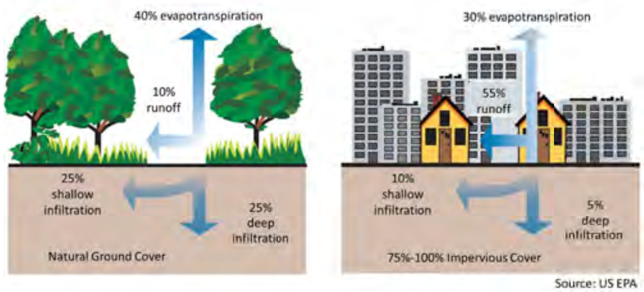
U.S. Environmental Protection Agency (EPA)
http://www.epa.gov/owow_keep/NPS/whatis.html

Common Pollutants in Runoff

- Trash/Floatables
- Nutrients
- Oils, Grease
- Metals
- Sediment
- Bacteria
- Heat



Land Cover & Stormwater



Where does the stormwater go?

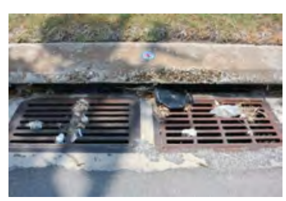
Sanitary Sewer System

Storm Sewer System

What's the difference?

Sanitary sewer systems usually lead to → Sewage treatment facilities

What's the difference?



Storm sewer systems usually lead to → Streams and Rivers

What is Green Stormwater Infrastructure?

Constructed features that mimic the predevelopment hydrology of the site.

- Bioretention basins and swales
- Constructed wetlands
- Vegetated filter strips
- Cisterns
- Permeable pavement and pavers
- Disconnected downspouts
- Raingardens

Adding Green Stormwater Infrastructure to a Site

- Use slopes and adjacencies to impervious cover
- Should be used as an additional amenity
- Increased vegetation and shade
- Pollinator habitat
- Reduced pollutant loads from parking surfaces, roads, and roofs

Permeable Pavement

Bioswale

Rainwater Capture

Bioretention

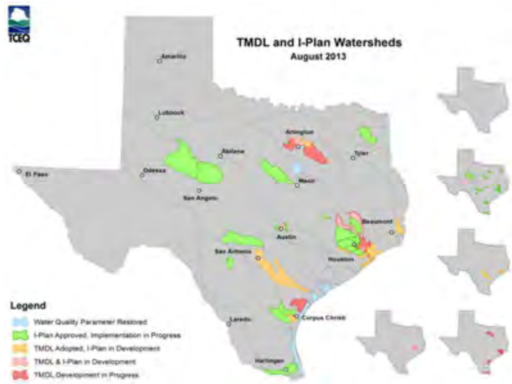
Common Permanent On-site Stormwater BMPs

GSI Master Plan Project Goal

- Build on recommendations made in the
  - Upper SA River Watershed Protection Plan and Implementation Plan,
  - Investments SARA has made in water quality models, and
  - watershed master plan integration
- To develop a Green Stormwater Infrastructure (GSI) Master Plan for the Upper SA River Watershed in Bexar County.

Strategic Approach

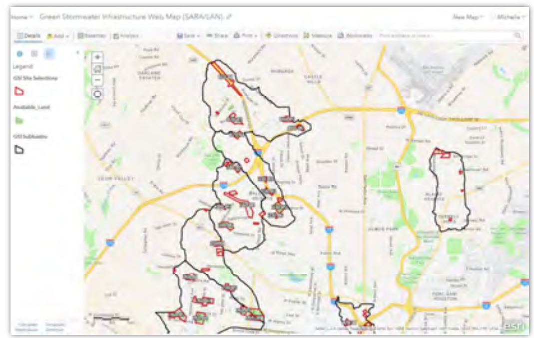
- Follow guidance in the Upper SA Watershed Protection Plan
- Long-term, phased approach
- Link to City of San Antonio's SATomorrow and Climate Action plans



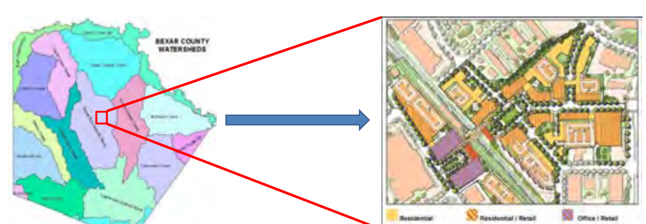
Project Grant Scope

- ✓Priority Area Identification
- ✓GIS Assessment for GSI Implementation Opportunities
- ✓Evaluation of GSI opportunities
- ✓Model Sites with GSI BMPs
- Prioritize GSI Opportunities based on TBL analysis and
- Stakeholder Engagement
- Report Development

Site Selections



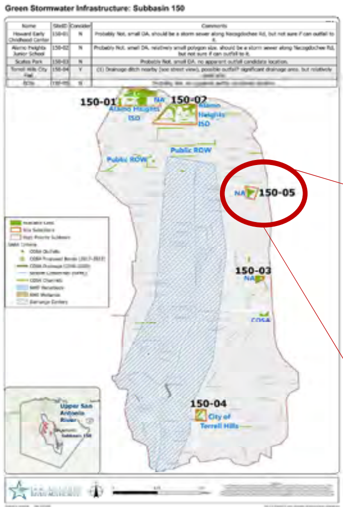
Concept of Watershed to Site-Scale Modeling



HSPF Watershed Scale Model

HSPF Site Scale Model with Physical Processing of BMPs

CoSA ROW in Terrell Heights: Neighborhood Association & Community Garden

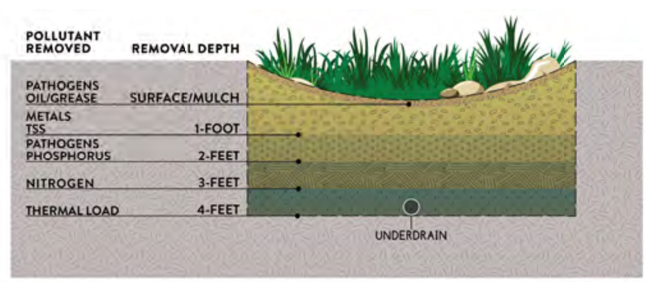


Site 150-05 – Terrell Heights Community Garden

Bioretention Basin

- Captures floatables
- Reduces sediment, bacteria, chemical loads
- Moderates stormwater temperature
- Provides habitat and shade
- Can help alleviate flooding

Bioretention Treatment Profile



Triple Bottom Line (TBL) Analysis of GSI BMPs

- Monetizes the benefits and costs of activities in three functions: economic, social, and environmental.
- It will denote a broad array of community benefits (and cost assessment) to GSI and LID designs such as:

- Air Pollution and Carbon Emissions
- Flood Risk Mitigation
- Heat Mortality Reduction
- Water Quality Improvement
- Water Quantity Impact
- Habitat Value
- Recreational Use
- Property Uplift
- Health Outcomes
- Educational Value
- Avoided gray infrastructure costs

Stakeholder Engagement

- The City of San Antonio
  - Office of Sustainability
  - Planning & Community Development
  - Transportation & Capital Improvement
  - Parks and Recreation
- Bexar County Stormwater
- Suburban Cities in priority areas
- Bexar Regional Watershed Management WTC
- Homeowners & Neighborhood Associations
- SA Housing Authority
- SA 2030 District
- SA Climate Ready
- SA Tomorrow Regional Centers

Major Deliverables

- Analysis
  - Identify Water Quality High Priority Areas, GIS Data Assessment, GSI Identification & Modeling, Prioritization and Cost Report
- Stakeholder Engagement
  - Community Workshops, present analysis findings in prioritized areas, include feedback in final report
- GSI Master Plan
  - Triple Bottom Line (TBL) and Sustainable Return On Investment (SROI) Evaluation and Report, GSI Master Plan
- Final Report

Proposed Signage for Terrell Heights Site-

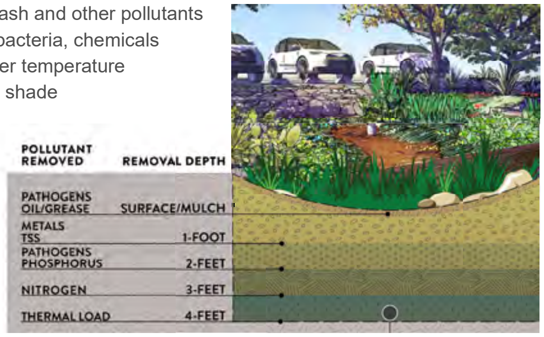
(Next two slides would be the front & back)

What do you think?

- What is your impression of the proposed bioretention area, also known as a rain garden?
- Do you have concerns about the addition of a bioretention area to this green space?
- What do you like about the proposed project?
- What would you change, if anything?
- Do you think this project is feasible?
- Do you know of any funding sources to implement the project or help maintain it if it were constructed?

Bioretention Basins are designed to:

- Capture floatable trash and other pollutants
- Reduce sediment, bacteria, chemicals
- Moderate stormwater temperature
- Provide habitat and shade
- Alleviate flooding



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SAN ANTONIO RIVER AUTHORITY

EPA United States Environmental Protection Agency

To learn more visit: sariverauthority.org/sustainability

Appendix I. Workshop 2: The City of San Antonio Public Works Department meeting invitation, agenda, and presentation held on March 9, 2021.

Meeting with Robert Reyna, Abigail Bush, Erin Cavazos.

Michelle E. Garza

Subject:	CoSA Public Works Department - Input Requested
Start:	Tue 3/9/2021 11:30 AM
End:	Tue 3/9/2021 12:00 PM
Recurrence:	(none)
Meeting Status:	Meeting organizer
Organizer:	Michelle E. Garza
Required Attendees	Roberto Reyna (PWD); Erin Cavazos

Meeting to discuss and plan Public Works workshop for GSI Master Plan input.

Agenda:

From: Michelle E. Garza <megarza@sariverauthority.org>
Sent: Thursday, February 11, 2021 3:17 PM
To: Roberto Reyna (PWD) <Roberto.Reyna@sanantonio.gov>
Cc: Erin Cavazos <ecavazos@sariverauthority.org>; Karen Bishop <kbishop@sariverauthority.org>
Subject: [EXTERNAL] CoSA Public Works Department - Input Requested

Good afternoon, Roberto,

I hope you are doing well. I am not sure if you remember me, but I've met you at BRWM meetings.

I am reaching out to request feedback as part of the next phase of the GSI Master Plan, a EPA/TCEQ 319 Grant, that you may remember from presentations I've made to the BRWM group. We are looking for feedback from property owner/stakeholders on the sites that were modeled. I would like to present the work done on the City ROW sites for feedback in a short virtual workshop. I have attached a brief presentation to give you a visual overview of the project and the sites.

Below is a summary of the grant project and outline of the virtual workshop.

The Upper SA River Watershed GSI Master Plan is an EPA/TCEQ Clean Water Act 319(h) Grant Project. The plan builds on recommendations made in the Upper SA River Watershed Protection Plan and Implementation Plan, Investments SARA has made in water quality models, and watershed master plan integration to develop a GSI Master Plan for the Upper SA River Watershed in Bexar County.

The River Authority is implementing this project to model select locations within targeted sub-watersheds to identify opportunities for implementing GSI and then to share outcomes with key stakeholders toward greater understanding of the opportunities, barriers, costs, etc. A priority is being given to space within public rights of way and/or on public lands. As I mentioned, the River Authority identified and modeled four City parks with GSI BMPs. I would like the opportunity to talk with you and other City of San Antonio Public Works staff whom you recommend regarding the results and the City's thoughts about them.

Stakeholder Workshop Outline:
The purpose is to share the project with property owners and stakeholders (CoSA Public Works) to gather feedback and input on the work done to identify and model GSI/LID BMPs on public property as well as implementation potential.

- Overview of the GSI Master Plan - EPA 319 Grant Project
- Review GSI opportunities in City ROW sites (Terrell Heights Community Garden (Larchmont Dr. and Greenwich Blvd.) and Sydney Brooks Drive and City-Base Landing)
  - Provide an overview of the site's water quality modeling, triple bottom line analysis, and concept-level designs
- Gather feedback on GSI feasibility, funding, and barriers as well as priority of the two potential projects

My goal is to hold this meeting at the end of February, early March timeframe, to stay on the grant project schedule. Please let me know if you'd like to discuss this in more detail. I am happy to set up a quick call or feel free to give me a call at your convenience at 210-302-3265.

I look forward to talking with you.

Thank you for your help.

Michelle E. Garza
Stormwater Analyst, Sustainable Infrastructure Unit
San Antonio River Authority
megarza@sariverauthority.org
(210) 302-3265

Meeting presentation (next page):

SAN ANTONIO RIVER AUTHORITY

Upper San Antonio River Watershed Green Stormwater Infrastructure (GSI) Master Plan

EPA/TCEQ Clean Water Act 319(h) Grant Project

Project Goal

- Build on recommendations made in the
  - Upper SA River Watershed Protection Plan and Implementation Plan,
  - Investments SARA has made in water quality models, and
  - watershed master plan integration
- To develop a Green Stormwater Infrastructure (GSI) Master Plan for the Upper SA River Watershed in Bexar County.

Strategic Approach

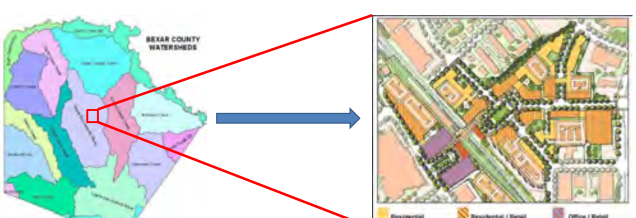
- Follow guidance in the Upper SA Watershed Protection Plan
- Long-term, phased approach
- Link to City of San Antonio's SATomorrow and Climate Action plans

Project Grant Scope

- ✓Priority Area Identification
- ✓GIS Assessment for GSI Implementation Opportunities
- ✓Evaluation of GSI opportunities
- ✓Model Sites with GSI BMPs
- Prioritize GSI Opportunities based on TBL analysis and
- Stakeholder Engagement
- Report Development

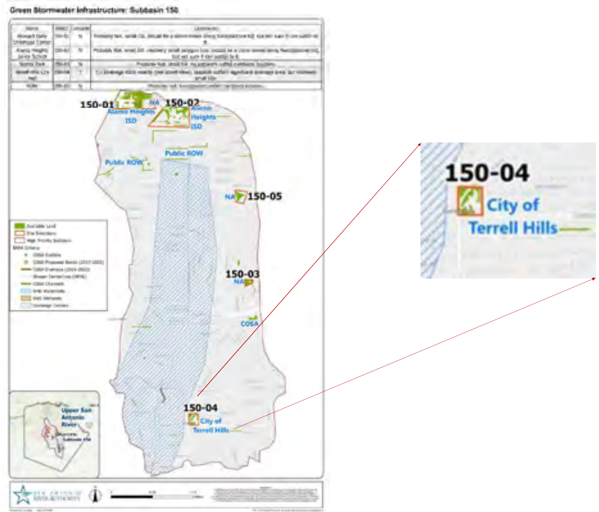
Site Selections

Concept of Watershed to Site-Scale Modeling

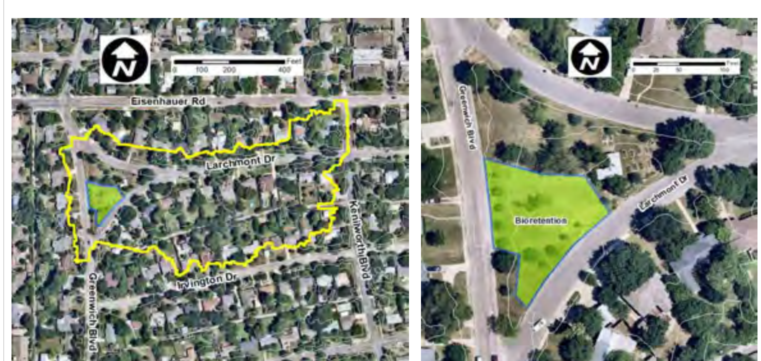


HSPF Watershed Scale Model

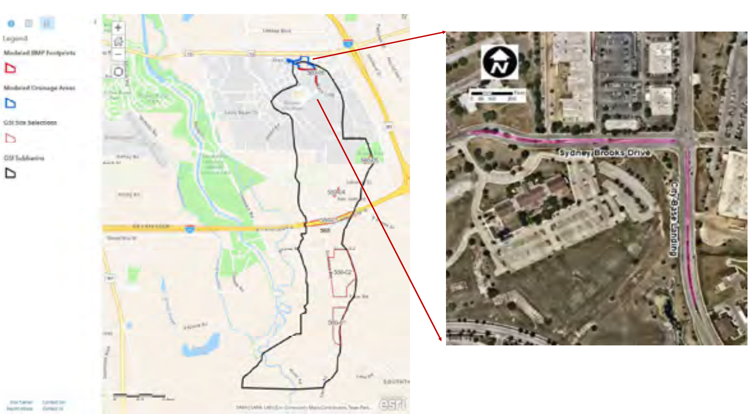
HSPF Site Scale Model with Physical Processing of BMPs



Site 150-05 – Terrell Heights Community Garden



Site 560-06 Sydney Brooks Drive/City-Base Landing



Stakeholder Engagement

- The City of San Antonio
  - Office of Sustainability
  - Planning & Community Development
  - Transportation & Capital Improvement
  - Parks and Recreation
- Bexar County Stormwater
- Suburban Cities in priority areas
- Bexar Regional Watershed Management WTC
- Homeowners & Neighborhood Associations
- SA Housing Authority
- SA 2030 District
- SA Climate Ready
- SA Tomorrow Regional Centers

Major Deliverables

- Analysis
  - Identify Water Quality High Priority Areas, GIS Data Assessment, GSI Identification & Modeling, Prioritization and Cost Report
- Stakeholder Engagement
  - Community Workshops, present analysis findings in prioritized areas, include feedback in final report
- GSI Master Plan
  - Triple Bottom Line (TBL) and Sustainable Return On Investment (SROI) Evaluation and Report, GSI Master Plan
- Final Report

Appendix J: Workshop 3: Brooks Development Authority meeting invitation, participation list, and presentation held on March 25, 2021.

Contract # 90204 - Upper San Antonio River Watershed Protection Plan Implementation - Green Stormwater Infrastructure (GSI) Master Plan

Meeting Participation List:

- Brooks Development Authority
    - Carlos Salinas, carlos@livebrooks.com
    - Amber Gilbert, amber@livebrooks.com
    - Mark Cook, mark@livebrooks.com
    - Tom Garcia, tom@livebrooks.com
- Brooks Development Authority Developer Consultant
    - Curtis Lee, CLee@pape-dawson.com

Meeting Presentation (next page)

Upper San Antonio River Watershed Green Stormwater Infrastructure (GSI) Master Plan

EPA/TCEQ Clean Water Act 319(h) Grant Project
Brooks Development Authority

ACKNOWLAGE OF FINANCIAL SUPPORT

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

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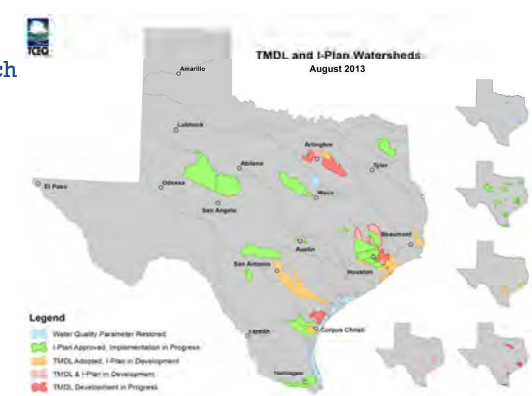
Project Goal

- Build on recommendations made in the
  - Upper SA River Watershed Protection Plan and Implementation Plan,
  - Investments SARA has made in water quality models, and
  - Watershed master plan integration
- To develop a Green Stormwater Infrastructure (GSI) Master Plan for the Upper SA River Watershed in Bexar County.

Strategic Approach

- Follow guidance in the Upper SA Watershed Protection Plan
- Long-term, phased approach
- Link to City of San Antonio's SATomorrow and Climate Action plans



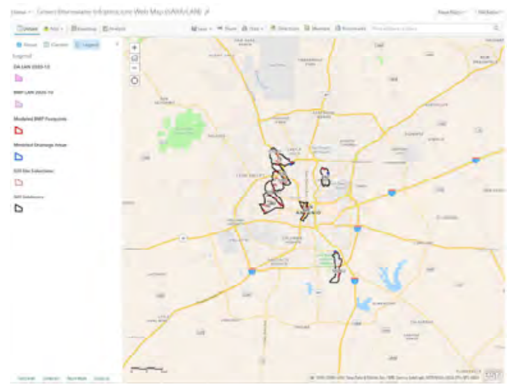
Water Quality Watershed Master Planning

- **To date: mostly <u>Qualitative</u>**
  - Best Management
  - To the extent possible/practicable
- **303(d)/ Impairments listing based on monitoring data (CRP)**
  - Quarterly monitoring – temporal gap
  - Limited SWQM station locations – spatial gap
- **Best Management Practices (BMPs)/Low Impact Development (LID) planning:**
  - Little modeling; the "right kind" of models don't exist.
  - Build first, then monitor to see effectiveness

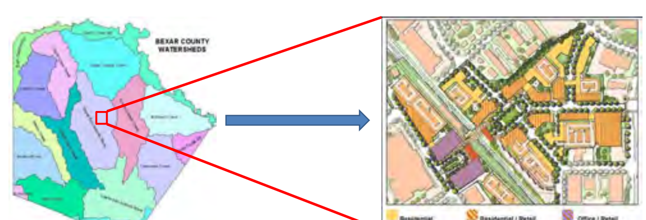
Project Grant Scope

✓Priority Area Identification
✓Available Land Assessment for GSI Opportunities
✓Evaluation of GSI Opportunities
✓Model Sites with GSI BMPs
•Prioritize GSI Opportunities based on TBL analysis and
•Stakeholder Engagement
•Report Development

Available Sites Identified in Priority Areas



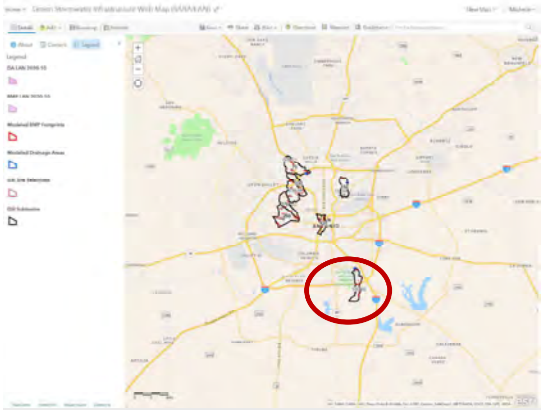
Concept of Watershed to Site-Scale Modeling



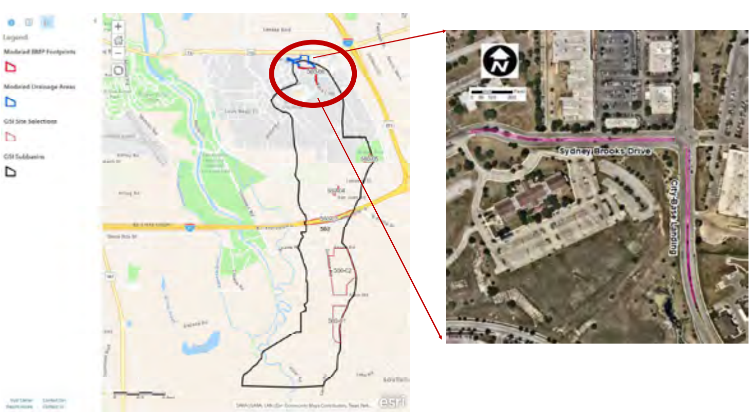
HSPF Watershed Scale Model

HSPF Site Scale Model with Physical Processing of BMPs

Priority Subbasin 560



Site 560-06 Sydney Brooks Drive/City-Base Landing



Triple Bottom Line (TBL) Analysis of GSI BMPs

- Monetizes the benefits and costs of activities in three functions: economic, social, and environmental.
- It will denote a broad array of community benefits (and cost assessment) to GSI and LID designs such as:

- Air Pollution and Carbon Emissions
- Flood Risk Mitigation
- Heat Mortality Reduction
- Water Quality Improvement
- Water Quantity Impact

- Habitat Value
- Recreational Use
- Property Uplift
- Health Outcomes
- Educational Value
- Avoided gray infrastructure costs

Stakeholder Engagement

- The City of San Antonio
  - Office of Sustainability
  - Planning & Community Development
  - Transportation & Capital Improvement
  - Parks and Recreation
- Bexar County Stormwater
- Suburban Cities in priority areas
- Bexar Regional Watershed Management WTC
- Homeowners & Neighborhood Associations
- SA Housing Authority
- SA 2030 District
- SA Climate Ready
- SA Tomorrow Regional Centers

Major Deliverables

- Analysis
  - Identify Water Quality High Priority Areas, GIS Data Assessment, GSI Identification & Modeling, Prioritization and Cost Report
- Stakeholder Engagement
  - Community Workshops, present analysis findings in prioritized areas, include feedback in final report
- GSI Master Plan
  - Triple Bottom Line (TBL) and Sustainable Return On Investment (SROI) Evaluation and Report, GSI Master Plan
- Final Report

What do you think?

- What is your impression of the proposed GSI BMPs?
- Do you have concerns about the proposed bioswale in the Brooks center strip?
- What do you like about the proposed projects?
- What would you change, if anything?
- Do you think these projects are feasible?
- Do you know of any funding sources to implement the project or help maintain it if it were constructed?
- How would you rank the two projects and why?

Appendix K. Workshop 4: City of San Antonio Park and Recreation Meeting on March 31, 2021.

Meeting invitation, agenda, and participant list:

From: Michelle E. Garza
Sent: Tuesday, March 23, 2021 11:29 AM
To: sandy.jenkins@sanantonio.gov; Grant Ellis (Parks) <Grant.Ellis@sanantonio.gov>; michael.baldwin@sannatonio.gov; bill.pennell@sanantoni.gov; Daniel Leal (Parks) <Daniel.Leal@sanantonio.gov>; Melinda Cerda (Parks) <Melinda.Cerda@sanantonio.gov>
Cc: Karen Bishop <kbishop@sariverauthority.org>; Melissa Bryant <mbryant@sariverauthority.org>; Michelle E. Garza <megarza@sariverauthority.org>
Subject: SA River Authority GSI Master Plan Project's Parks Results

Good afternoon,

The San Antonio River Authority would like to present the Green Stormwater Infrastructure (GSI) Master Plan grant project to your department for feedback. Part of the project modeled GSI in four CoSA Parks: Windsor Park, Lee's Creek Park, Monterrey Park, and Rosedale Park.

Please fill out the straw poll linked below, to find a day and time that works for this group. Feel free to forward to others you would like to invite.

https://strawpoll.com/vg5qq21yg

Attached is an overview of the GSI Master Plan project and parks modeled, if you'd like to review the project prior to the meeting. These are some questions that will be asked about the project's finding/proposal:

- What are your impression of the proposed GSI BMPs in each site?
- What concerns do you have about each site's GSI BMPs?
- What do you like about these proposed park projects?
- What would you change, if anything?
- How would you rank them in order of implementation and why?
- Do you think these projects are feasible?
- What do you think the community would think about the implementation of GSI BMPs in parks?
- Do you know of any work planned for these parks that GSI could be included in?
- Do you know of any potential funding sources to implement these projects?

Please reach out to me if you have any questions or concerns.

Thank you,

Michelle E. Garza
Stormwater Analyst
Sustainable Infrastructure Unit
O: (210) 302-3265 | C: (210) 859-8867 | megarza@sariverauthority.org
600 E. Euclid Ave. |San Antonio, TX. 78212 | www.sariverauthority.org

Meeting presentation (next page):

Upper San Antonio River Watershed
Green Stormwater Infrastructure (GSI) Master Plan

EPA/TCEQ Clean Water Act 319(h) Grant Project

City of San Antonio – Parks and Recreation Department

ACKNOWLAGE OF FINANCIAL SUPPORT

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

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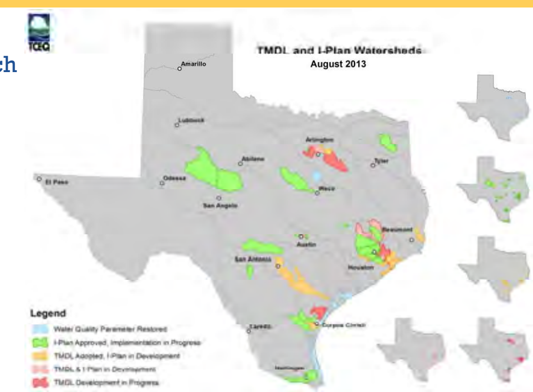
United States Environmental Protection Agency

Project Goal

- Build on recommendations made in the
  - Upper SA River Watershed Protection Plan and Implementation Plan,
  - Investments SARA has made in water quality models, and
  - watershed master plan integration
- To develop a Green Stormwater Infrastructure (GSI) Master Plan for the Upper SA River Watershed in Bexar County.

Strategic Approach

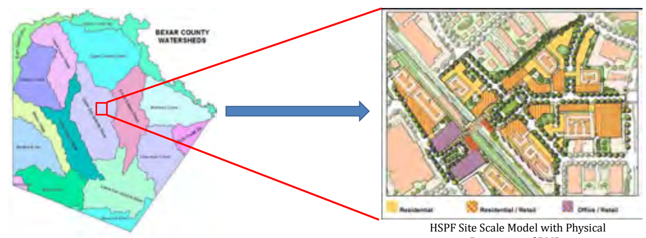
- Follow guidance in the Upper SA Watershed Protection Plan
- Long-term, phased approach
- Link to City of San Antonio's SATomorrow and Climate Action plans



Project Grant Scope

✓Priority Area Identification
✓GIS Assessment for GSI Implementation Opportunities
✓Evaluation of GSI opportunities
✓Model Sites with GSI BMPs
•Prioritize GSI Opportunities based on TBL analysis and
•Stakeholder Engagement
•Report Development

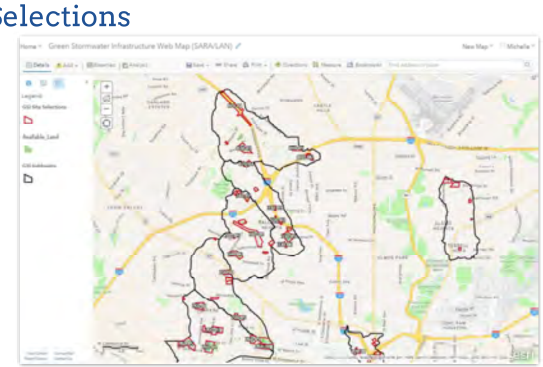
Concept of Watershed to Site-Scale Modeling



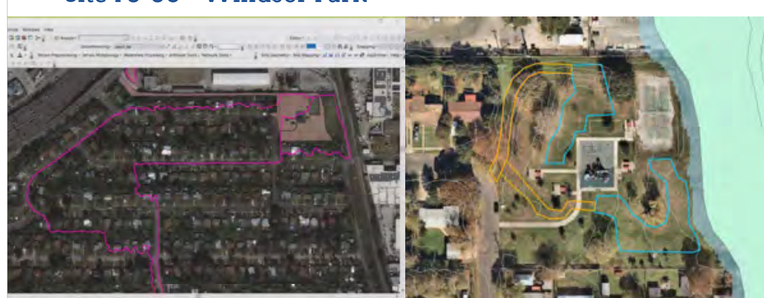
HSPF Watershed Scale Model

HSPF Site Scale Model with Physical Processing of BMPs

Site Selections



Site 70-06 – Windsor Park




WINDSOR PARK
Character Images


MONTERREY PARK
W COMMERCE STREET


260-04N
MONTERREY PARK
FORTUNA STREET
Character Images


270-06
ROSEDALE PARK
Character Images

Committed to Safe, Clean, Enjoyable Creeks and Rivers.

Major Deliverables

- Analysis
  - Identify Water Quality High Priority Areas, GIS Data Assessment, GSI Identification & Modeling, Prioritization and Cost Report
- Stakeholder Engagement
  - Community Workshops, present analysis findings in prioritized areas, include feedback in final report
- GSI Master Plan
  - Triple Bottom Line (TBL) and Sustainable Return On Investment (SROI) Evaluation and Report, GSI Master Plan
- Final Report

Committed to Safe, Clean, Enjoyable Creeks and Rivers.

Stakeholder Engagement

- The City of San Antonio
  - Office of Sustainability
  - Planning & Community Development
  - Transportation & Capital Improvement
  - Parks and Recreation
- Bexar County Stormwater
- Suburban Cities in priority areas
- Bexar Regional Watershed Management WTC
- Homeowners & Neighborhood Associations
- SA Housing Authority
- SA 2030 District
- SA Climate Ready
- SA Tomorrow Regional Centers

Committed to Safe, Clean, Enjoyable Creeks and Rivers.

What do you think?

- What is your impression of the proposed GSI BMPs?
- Do you have concerns about the proposed GSI BMPs in each park?
- What do you like about the proposed projects?
- What would you change, if anything?
- Do you think these projects are feasible?
- Do you know of any funding sources to implement the project or help maintain it if it were constructed?
- How would you rank the projects and why?

Committed to Safe, Clean, Enjoyable Creeks and Rivers.


SAN ANTONIO
RIVER AUTHORITY
Thank you!
megarza@sariverauthority.org
www.sara-tx.org
Committed to Safe, Clean, Enjoyable Creeks and Rivers.
17

Appendix L. Workshop 5: San Antonio Housing Authority May 4, 2021, meeting details.

Michelle E. Garza

From: Michelle E. Garza
Sent: Tuesday, May 4, 2021 11:10 AM
To: Beth Keel; sylvia_molina@saha.org; michael_lopez@saha.org; wendellyn_miller@saha.org; timothy_alcott@saha.org; Melissa Garza; david_casso@saha.org; tristan_tovar@saha.org
Cc: Michelle E. Garza
Subject: RE: SAHA - Input Requested on SA River Authority GSI Master Plan's SAHA sites
Attachments: GSI Master Plan_SAHA_Update_20210504.pdf; Final LID for Developers Brochure.pdf

Thank you for your time today. Please find the presentation I gave on the Green Infrastructure Master Plan grant project attached. I have also included some additional resources we discussed for use in SAHA projects going forward.

Also attached and linked below is the

- LID Developer Brochure that discusses the City's Credit/Offsets
- LID Design Guidance Manual (with O&M guidelines)
    - https://www.sariverauthority.org/sites/default/files/2019-08/SARB%20LID%20Technical%20Design%20Manual%202nd%20Edition.pdf
- Sustainability webpage
    - with the Green Infrastructure web map (where you can see rebate and River Authority project details
        - https://www.sariverauthority.org/be-river-proud/sustainability
    - LID Rebate details
        - https://www.sariverauthority.org/be-river-proud/sustainability/rebates

The River Authority's Sustainable Infrastructure Team is available to help with your master planning efforts to include LID/GSI BMPs, review GSI/LID plan sets, help with GSI/LID Rebate applications, and present on topics of interest, etc.

Please reach out to me anytime.

Thank you again,

Michelle E. Garza
Stormwater Analyst, Sustainable Infrastructure Unit
San Antonio River Authority
O: (210) 302-3265 | C: (210) 859-8867 | megarza@sariverauthority.org
600 E. Euclid Ave. |San Antonio, TX. 78212 | www.sariverauthority.org

-----Original Appointment-----
From: Michelle E. Garza
Sent: Wednesday, April 21, 2021 12:24 PM
To: Michelle E. Garza; Beth Keel
Cc: sylvia_molina@saha.org; tristan_tovar@saha.org; wendellyn_miller@saha.org; michael_lopez@saha.org; timothy_alcott@saha.org; Melissa Garza; david_casso@saha.org
Subject: SAHA - Input Requested on SA River Authority GSI Master Plan's SAHA sites
When: Tuesday, May 4, 2021 10:00 AM-11:00 AM (UTC-06:00) Central Time (US & Canada).
Where: Microsoft Teams Meeting
Importance: High

Microsoft Teams meeting

Join on your computer or mobile app
Click here to join the meeting
Learn More | Meeting options

This meeting is to discuss the next phase of the GSI Master Plan Grant the River Authority is working on with grant funding from the US EPA administered by the TCEQ. The piece I would like to present to SAHA relates to Tampico Apartments and another site, we modeled Pin Oak Apartments. I would like to share the results of our work to model water quality improvements, analysis on additional benefits, and concept designs for SAHA's feedback. I have attached my presentation if you would like to review it prior to the meeting.

Below is a summary of the grant project and outline of the virtual meeting/workshop.

The Upper SA River Watershed GSI Master Plan is an EPA/TCEQ Clean Water Act 319(h) Grant Project. The plan builds on recommendations made in the Upper SA River Watershed Protection Plan and Implementation Plan, Investments SARA has made in water quality models, and watershed master plan integration to develop a GSI Master Plan for the Upper SA River Watershed in Bexar County.

The River Authority is implementing this project to model select locations within targeted sub-watersheds to identify opportunities for implementing GSI and then to share outcomes with key stakeholders toward greater understanding of the opportunities, barriers, costs, etc. A priority is being given to space within public rights of way and/or on public lands. As I mentioned, the River Authority identified and modeled four City parks with GSI BMPs. I would like the opportunity to talk with you and other SAHA staff whom you recommend regarding the results and SAHA's thoughts about them.

Stakeholder Workshop Outline:

The purpose is to share the project with property owners and stakeholders (SAHA) to gather feedback and input on the work done to identify and model GSI/LID BMPs on public property as well as implementation potential.

- Overview of the GSI Master Plan - EPA 319 Grant Project
- Review GSI opportunities in City parks sites (Tampico Apartments and Pin Oak Apartments)
  - Provide an overview of the site's water quality modeling, triple bottom line (economic, social, and environmental) cost/benefit analysis, and concept-level designs

- Gather feedback on GSI feasibility, funding, and barriers as well as priority of the potential projects

Please reach out to me anytime with questions.

Thank you!

Michelle E. Garza
Stormwater Analyst
Sustainable Infrastructure Unit
San Antonio River Authority
210.302.3265
megarza@sara-tx.org

United States Environmental Protection Agency

SAN ANTONIO RIVER AUTHORITY

Upper San Antonio River Watershed Green Stormwater Infrastructure (GSI) Master Plan

EPA/TCEQ Clean Water Act 319(h) Grant Project
San Antonio Housing Authority
5/4/2021

San Antonio River Authority Team

Project Manager	Michelle E. Garza
Water Quality Modeling, High Priority Areas, and BMP load	Sheeba Thomas
Watershed Master Plan & QAPP Manager	Erin Cavazos
LID Design Guidance & Expertise	Jake Aalfs
City/County Planning Guidance	Karen Bishop
Community Coordination & Outreach	Jeanette Gonzalez
LID BMP Evaluation and Report of TBL & SROI	Garrett Phillips
Financial Coordination	Sharon Otholt
GIS Data Evaluation & Expertise	Sara Mendiola
Cost Analysis & Expertise	Joshua Spencer

ACKNOWLAGEMENT OF FINANCIAL SUPPORT

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

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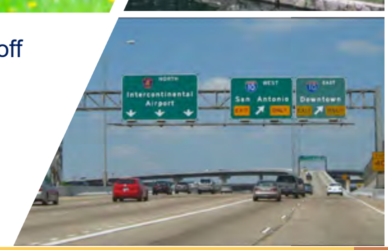
United States Environmental Protection Agency

Common Pollutants in Runoff

- Trash/Floatables
- Nutrients
- Oils, Grease
- Metals
- Sediment
- Bacteria
- Heat



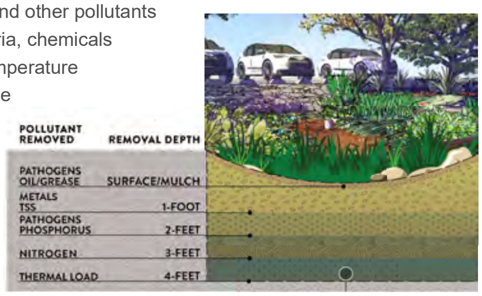
What is Green Stormwater Infrastructure (GSI)?

Constructed features that mimic the predevelopment hydrology of the site.

- Bioretention basins and swales
- Constructed wetlands
- Vegetated filter strips
- Cisterns
- Permeable pavement and pavers
- Disconnected downspouts
- Raingardens

Bioretention Basins are designed to:

- Capture floatable trash and other pollutants
- Reduce sediment, bacteria, chemicals
- Moderate stormwater temperature
- Provide habitat and shade
- Alleviate flooding



Permeable Pavement

Bioswale

Rainwater Capture

Bioretention

Common Permanent On-site Stormwater BMPs

Adding Green Stormwater Infrastructure to a Site

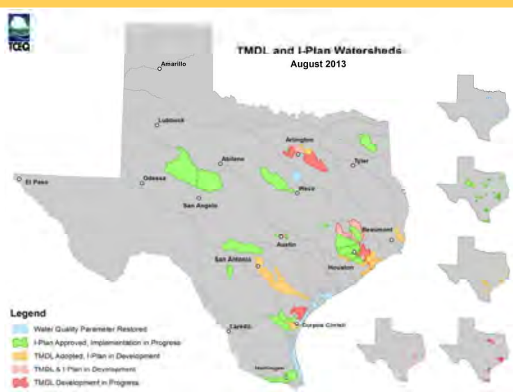
- Use slopes and adjacencies to impervious cover
- Should be used as an additional amenity
- Increased vegetation and shade
- Pollinator habitat
- Reduced pollutant loads from parking surfaces, roads, and roofs

GSI Master Plan Project Goal

- Build on recommendations made in the
  - Upper SA River Watershed Protection Plan and Implementation Plan,
  - Investments SARA has made in water quality models, and
  - watershed master plan integration
- To develop a Green Stormwater Infrastructure (GSI) Master Plan for the Upper SA River Watershed in Bexar County.

Strategic Approach

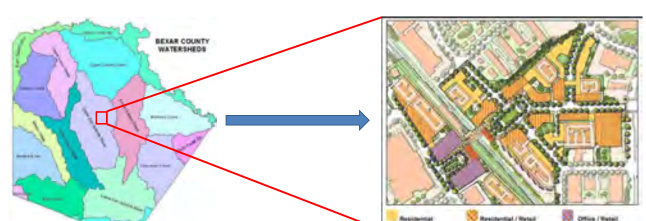
- Follow guidance in the Upper SA Watershed Protection Plan
- Long-term, phased approach
- Link to City of San Antonio's SATomorrow and Climate Action plans



Water Quality Watershed Master Planning

- **To date: mostly <u>Qualitative</u>**
  - Best Management
  - To the extent possible/practicable
- **303(d)/ Impairments listing based on monitoring data (CRP)**
  - Quarterly monitoring – temporal gap
  - Limited SWQM station locations – spatial gap
- **BMPs/LIDs planning:**
  - Little modeling; the "right kind" of models don't exist.
  - Build first, then monitor to see effectiveness

Concept of Watershed to Site-Scale Modeling



HSPF Watershed Scale Model

HSPF Site Scale Model with Physical Processing of BMPs

Project Grant Scope

- ✓ Start with High Priority Areas
- ✓ Assess them for GSI Opportunities
- ✓ Evaluate those GSI Opportunities
- ✓ Model Sites with GSI Best Management Practices (BMPs)

•Prioritize modeled GSI BMP Sites based on Triple Bottom Line (TBL) Cost/Benefit Analysis &

•Stakeholder Engagement

•Report Development

Triple Bottom Line (TBL) Analysis

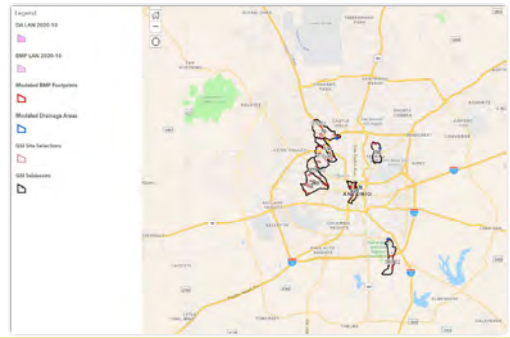
➢Monetizes the benefits and costs of activities in three functions: economic, social, and environmental.

➢It will denote a broad array of community benefits (and cost assessment) to GSI and LID designs such as:

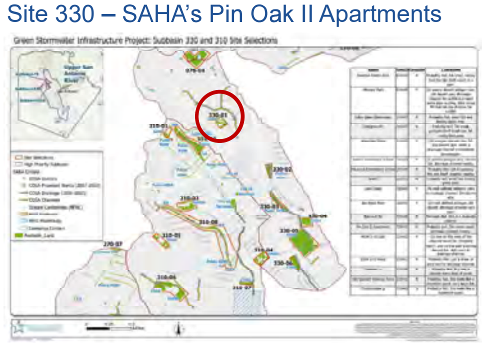
- •Air Pollution and Carbon Emissions
- •Flood Risk Mitigation
- •Heat Mortality Reduction
- •Water Quality Improvement
- •Water Quantity Impact

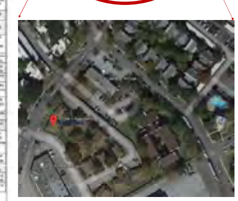
- •Habitat Value
- •Recreational Use
- •Property Uplift
- •Health Outcomes
- •Educational Value

Sites Identified within High Priority Subwatersheds



Site 330 – SAHA's Pin Oak II Apartments





Site 330 - SAHA Pin Oak II Apartments

Site 330 - SAHA Pin Oak II Apartments

Modeled flow and bacteria reduction over 4 –years

Table J-8 2007-2010 Flows and Loads of Subbasin 330 BMP Performance Evaluation Modeling

FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.6845	6.6845	0.0214	5.4214	1.2527	0.0000	0.0000	4.6929	2.0016	29.9%	15.9%
	Underdrain		5.4214	0.1156	1.8640	3.4412	0.0000	0.0000				
Bioretention S	Pond + Media	5.9117	5.9117	0.0195	4.8080	1.0841	0.0000	0.0000	5.3818	0.5234	8.9%	4.2%
	Underdrain		4.8080	0.5040		4.2977	0.0000	0.0064				
Total		12.6063		0.6604			0.0000	0.0064	10.0747	2.5250		20.0%

total rainfall (in)	131.314
drainage area (ac)	2.184
overall runoff coeff	0.527

BACT

BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3,048,619	3,048,619	392,548	2,413,604	242,462	0	0	1,159,602	1,889,017	62.0%	35.7%
	Underdrain		2,413,604	875,752	620,706	917,140	0	0				
Bioretention S	Pond + Media	2,236,636	2,236,636	292,535	1,773,410	170,690	0	0	1,133,102	1,103,076	49.3%	20.9%
	Underdrain		1,773,410	810,518		962,412	0	458				
Total		5,285,255		2,371,254			0	458	2,292,704	2,992,093		56.6%

NH3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	6.0617	6.0617	0.7206	4.4392	0.9019	0.0000	0.0000	2.8925	3.1693	52.3%	27.8%
	Underdrain		4.4392	1.3820	1.0666	1.9905	0.0000	0.0000				
Bioretention S	Pond + Media	5.3521	5.3521	0.6471	3.9267	0.7783	0.0000	0.0000	3.1418	2.2090	41.3%	19.4%
	Underdrain		3.9267	1.5658		2.3635	0.0000	0.0014				
Total		11.4139		4.3116			0.0000	0.0014	6.0342	5.3783		47.1%

NO3N

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	9.7031	9.7031	0.8482	7.7061	1.1488	0.0000	0.0000	4.6074	5.0957	52.5%	27.9%
	Underdrain		7.7061	1.9876	2.2599	3.4586	0.0000	0.0000				
Bioretention S	Pond + Media	8.5689	8.5689	0.7621	6.8195	0.9873	0.0000	0.0000	5.1887	3.3738	39.4%	18.5%
	Underdrain		6.8195	2.6115		4.2014	0.0000	0.0064				
Total		18.2720		6.2094			0.0000	0.0064	9.7961	8.4695		46.4%

ORGP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	3.8292	3.8292	0.0999	3.4914	0.2380	0.0000	0.0000	1.7802	2.0490	53.5%	28.4%
	Underdrain		3.4914	0.4225	1.5267	1.5422	0.0000	0.0000				
Bioretention S	Pond + Media	3.3792	3.3792	0.0896	3.0885	0.2011	0.0000	0.0000	2.2573	1.1092	32.8%	15.4%
	Underdrain		3.0885	1.0195		2.0562	0.0000	0.0127				
Total		7.2084		1.6314			0.0000	0.0127	4.0375	3.1582		43.8%

ORTHOP

BMP	Components	Inflow to BMP (lbs)	Inflow to component (lbs)	Decay (lbs)	Flow to underlayer (lbs)	Overflow (lbs)	Start storage (lbs)	End storage (lbs)	Outflow from BMP (lbs)	Load removed (lbs)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention N	Pond + Media	1.5294	1.5294	0.0401	1.3921	0.0972	0.0000	0.0000	0.7139	0.8155	53.3%	28.3%
	Underdrain		1.3921	0.1678	0.6076	0.6166	0.0000	0.0000				
Bioretention S	Pond + Media	1.3480	1.3480	0.0359	1.2305	0.0816	0.0000	0.0000	0.9015	0.4415	32.7%	15.3%
	Underdrain		1.2305	0.4055		0.8199	0.0000	0.0051				
Total		2.8774		0.6494			0.0000	0.0051	1.6154	1.2570		43.7%

Site 420 - SAHA: Tampico Apartments

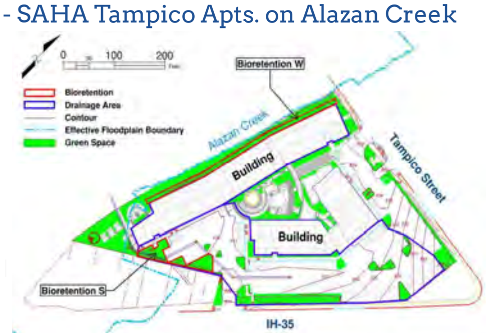
GSI Master Plan: Site 420

- Drainage Area

- Proposed BMP Footprint

- 100-Year Floodplain

Site 420 - SAHA Tampico Apts. on Alazan Creek



Modeling Results

Table K-9 2007-2010 Flows and Loads of Subbasin 420 BMP Performance Evaluation Modeling

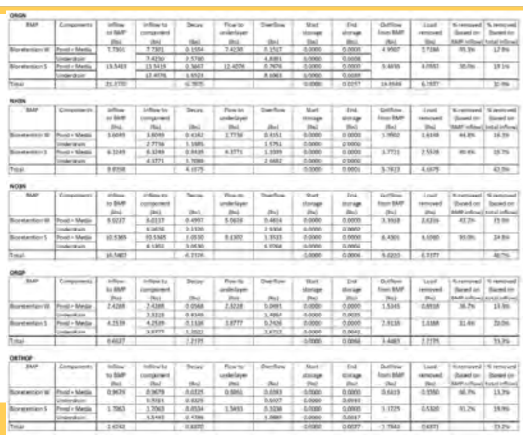
FLOW

BMP	Components	Inflow to BMP (ac-ft)	Inflow to component (ac-ft)	Evaporation (ac-ft)	Flow to underlayer (ac-ft)	Overflow (ac-ft)	Start storage (ac-ft)	End storage (ac-ft)	Outflow from BMP (ac-ft)	Flow removed (ac-ft)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	3.8158	3.8158	0.0149	3.1883	0.6127	0.0000	0.0000	3.3959	0.4087	10.7%	3.9%
	Underdrain		3.1883	0.3938		2.7932	0.0000	0.0112				
Bioretention S	Pond + Media	6.6937	6.6937	0.0212	5.0940	1.5784	0.0000	0.0000	6.1429	0.5345	8.0%	5.1%
	Underdrain		5.0940	0.5133		4.5645	0.0000	0.0162				
Total		10.5095		0.9432			0.0000	0.0274	9.5388	0.9432		9.0%

total rainfall (in)	112.271
drainage area (ac)	2.014
overall runoff coeff	0.558

BACT

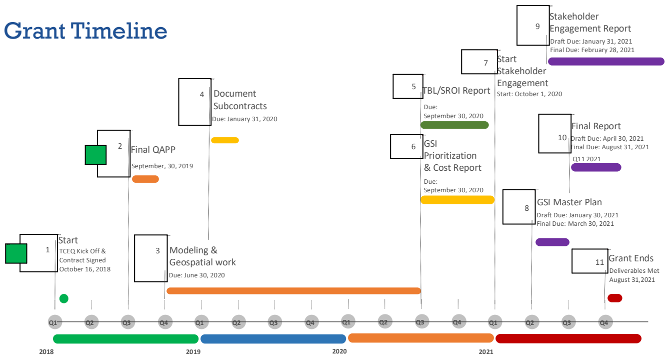
BMP	Components	Inflow to BMP (10^6)	Inflow to component (10^6)	Decay (10^6)	Flow to underlayer (10^6)	Overflow (10^6)	Start storage (10^6)	End storage (10^6)	Outflow from BMP (10^6)	Load removed (10^6)	% removed (based on BMP inflow)	% removed (based on total inflow)
Bioretention W	Pond + Media	2,254,051	2,254,051	264,910	1,930,367	58,776	0	0	1,027,293	1,226,747	54.4%	19.8%
	Underdrain		1,930,367	961,838		968,517	0	11				
Bioretention S	Pond + Media	3,952,892	3,952,892	585,217	3,089,285	278,391	0	0	1,978,373	1,974,501	50.0%	31.8%
	Underdrain		3,089,285	1,389,286		1,699,980	0	19				
Total		6,206,943		3,201,250			0	30	3,005,665	3,201,248		51.6%


ORGN

Stakeholder Engagement

- The City of San Antonio
  - Office of Sustainability
  - Planning & Community Development
  - Transportation & Capital Improvement (Public Works),
  - Parks and Recreation
- Bexar County Stormwater
- Suburban Cities in priority areas
- Bexar Regional Watershed Management WTC
- Homeowners & Neighborhood Associations
- SA Housing Authority
- SA 2030 District
- SA Climate Ready
- SA Tomorrow Regional Centers

Grant Timeline



Major Deliverables

- Analysis
  - Identify Water Quality High Priority Areas, GIS Data Assessment, GSI Identification & Modeling, Prioritization and Cost Report
- Stakeholder Engagement
  - Community Workshops, present analysis findings in prioritized areas, include feedback in final report
- GSI Master Plan
  - Triple Bottom Line (TBL) and Sustainable Return On Investment (SROI) Evaluation and Report, GSI Master Plan
- Final Report

What are your thoughts?

- What is your impression of the process to find targeted GSI opportunities?
- What are your thoughts on the proposed GSI BMP sites?
- Do you have concerns about any of the projects?
- What do you like about the proposed projects?
- What would you change, if anything?
- Do you think any of the projects are feasible?
- Do you know of any funding sources to implement any of them or help maintain them if constructed?
- How would you rank these projects?

GSI Master Plan: Upper SA River Watershed

- This project builds off the Upper San Antonio River Watershed Protection Plan (WPP) by developing a master plan for the use of green stormwater infrastructure (GSI) that incorporates stakeholder input to develop common goals and investment priorities for implementing GSI. Building on the River Authority's watershed scale models, sub-basin areas with high potential pollutant loads will be analyzed for sites that have the highest potential for GSI implementation effectiveness. For the recommended sites, the River Authority will develop site-scale models, concept-level designs, and Triple Bottom Line (social, environmental, economic) cost benefits estimates. The GSI Master Plan will include a recommended schedule of implementation, addressing the stakeholder process, costs, funding considerations, and the overall evaluation and prioritization process.