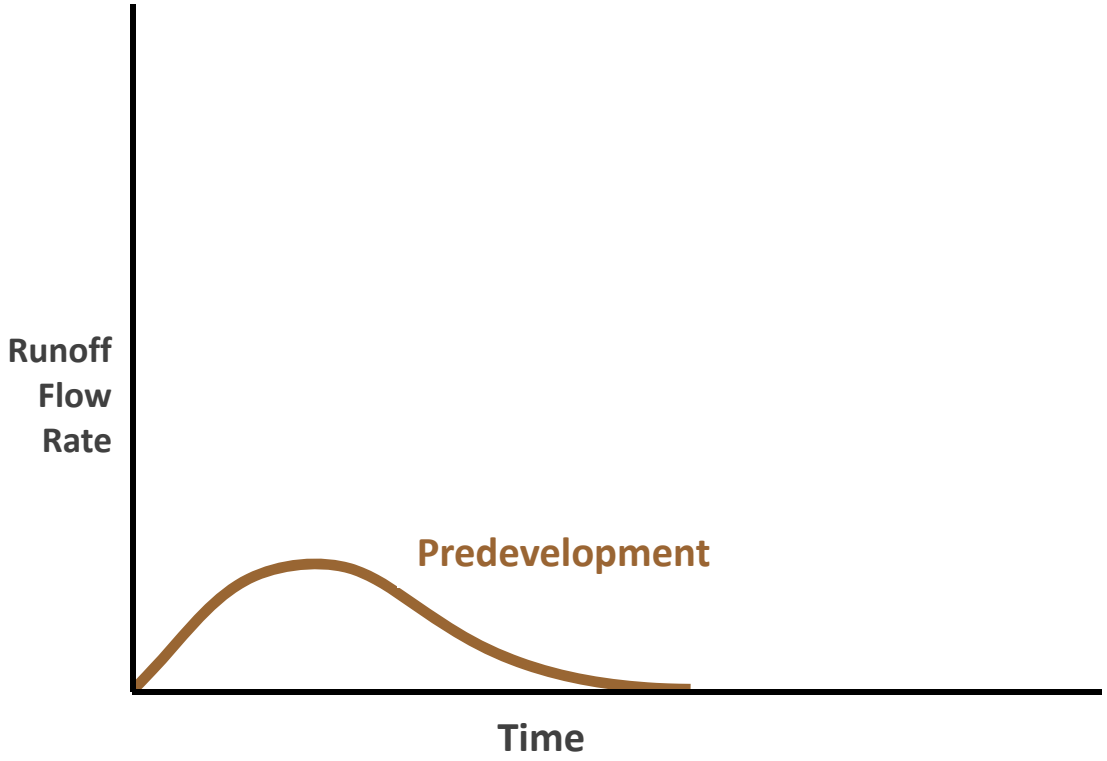
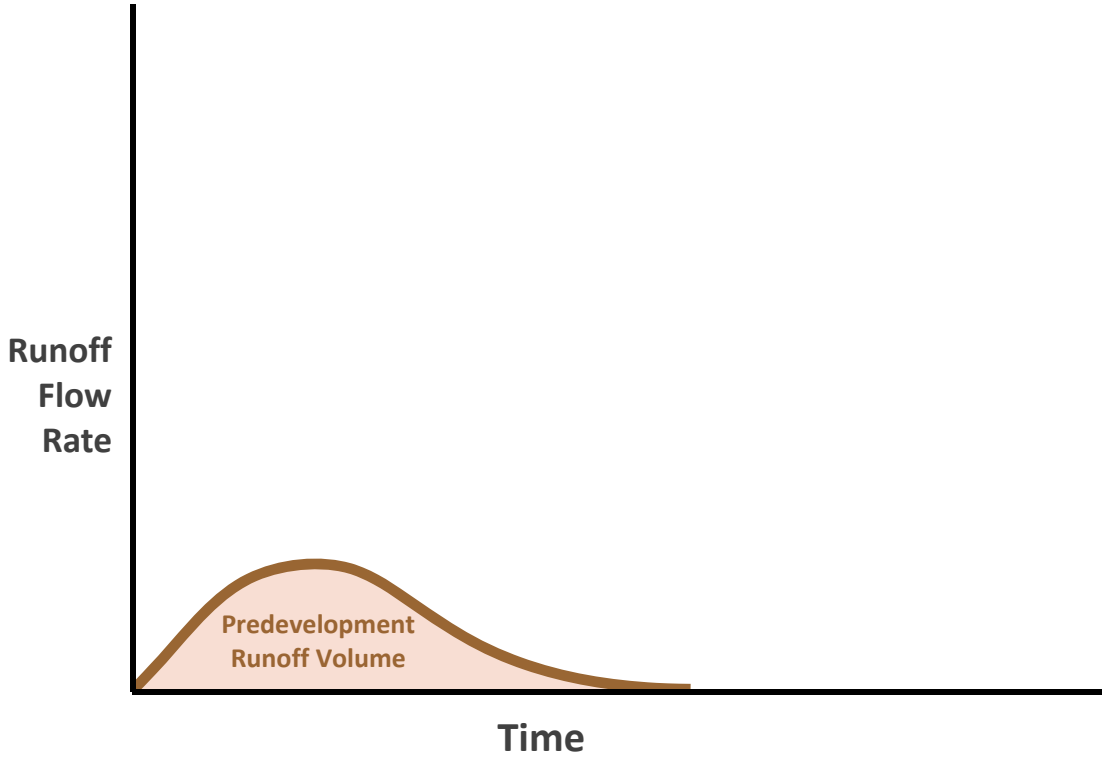
September 12, 2017

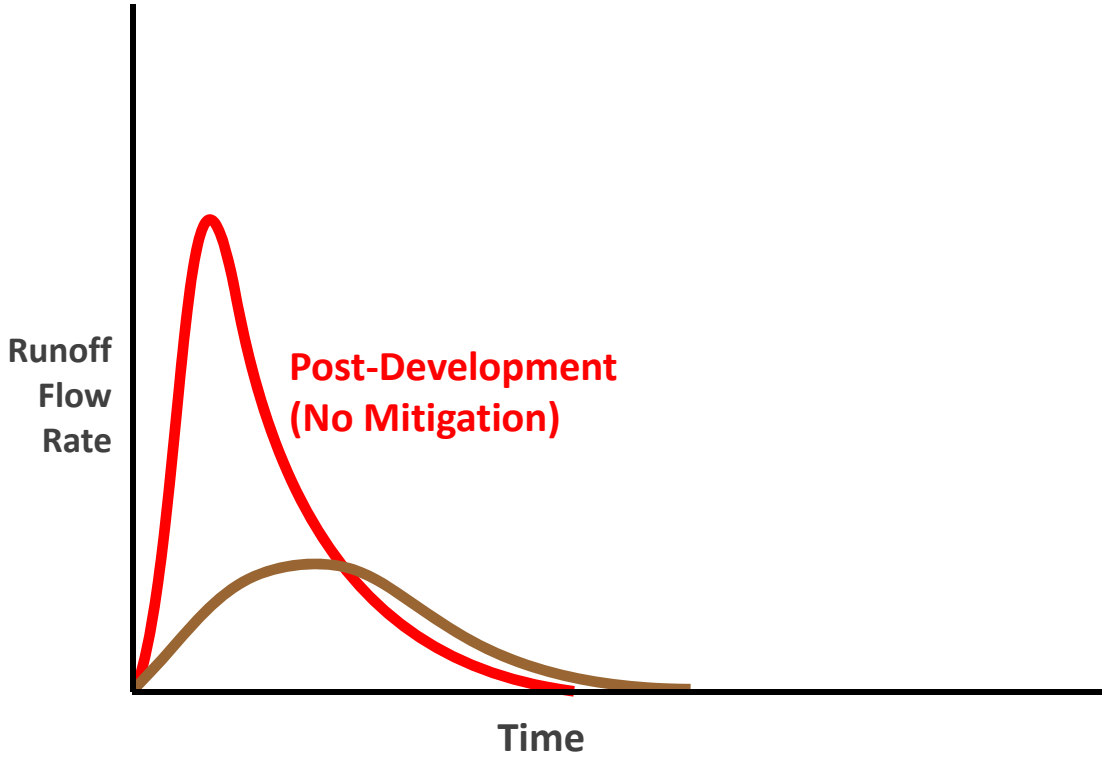
How to Develop Sustainably Using Green Stormwater Infrastructure

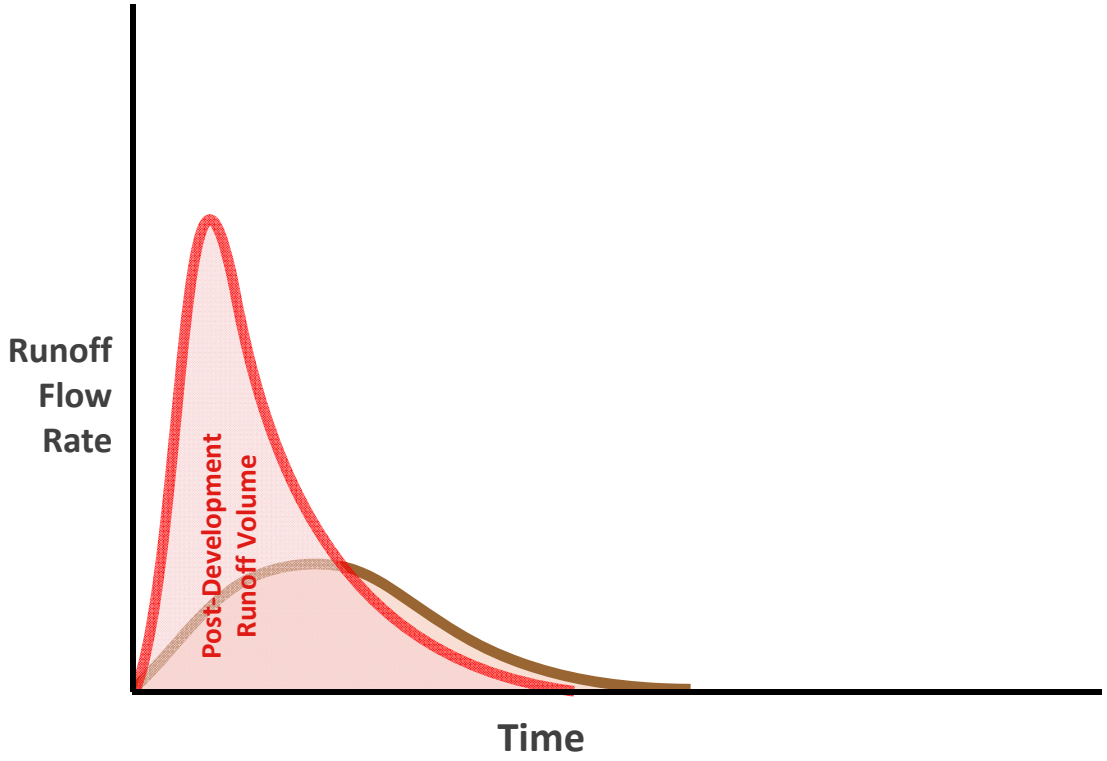
Michael F. Bloom, P.E., CFM, BCEE
Manager, Sustainability Practice

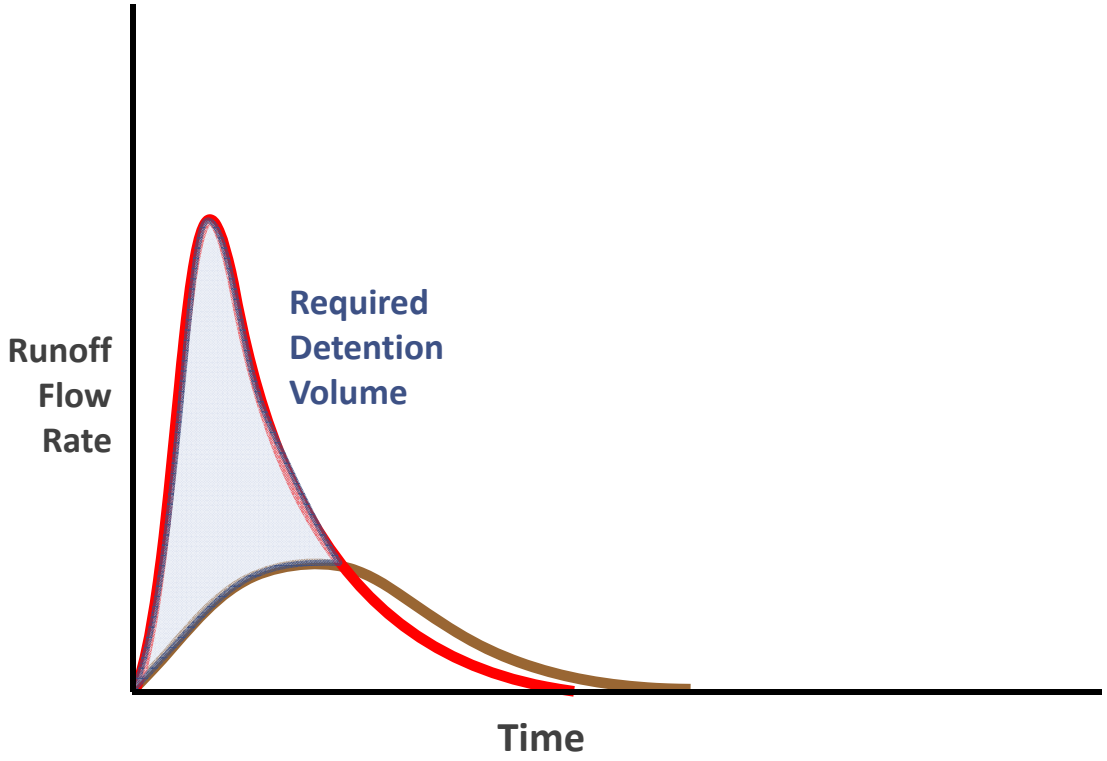
HYDROLOGY 101

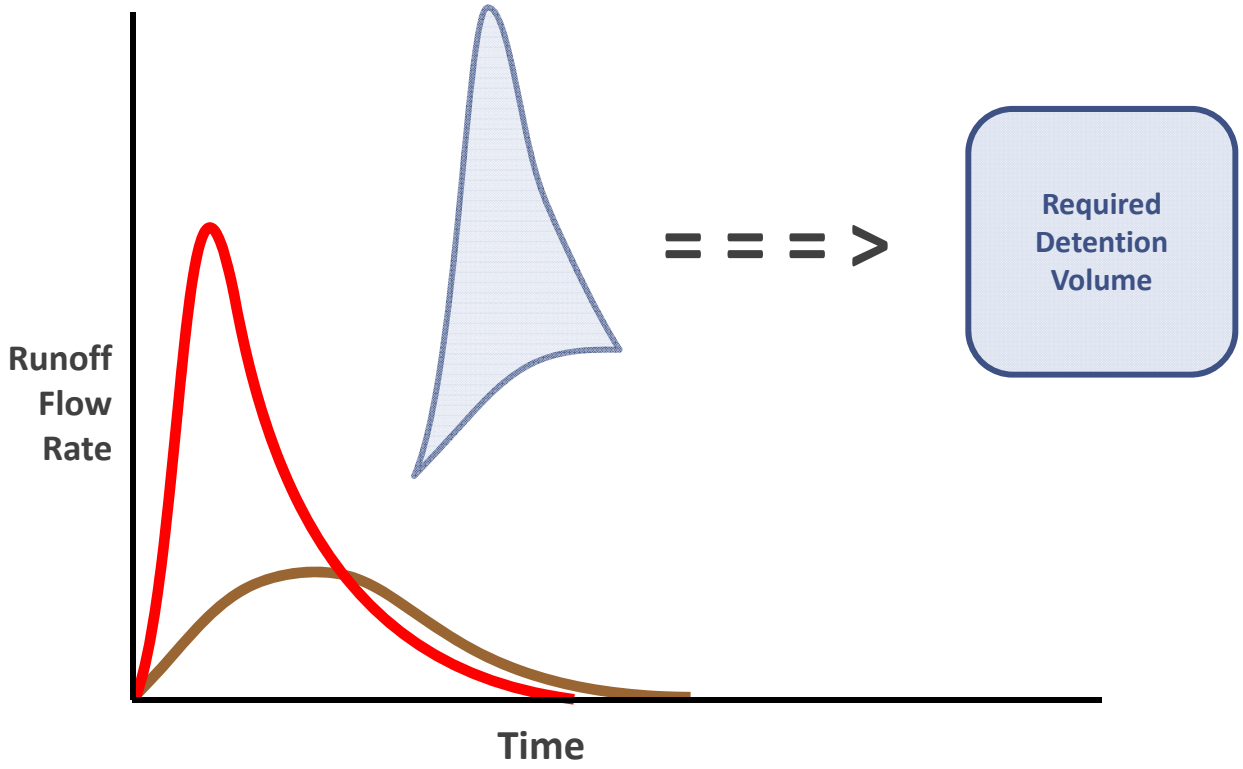

Runoff
Flow
Rate
Predevelopment
Time


Runoff
Flow
Rate
Predevelopment
Runoff Volume
Time


Runoff
Flow
Rate
Post-Development
(No Mitigation)
Time


Runoff
Flow
Rate
Post-Development
Runoff Volume
Time


Runoff
Flow
Rate
Required
Detention
Volume
Time


Runoff
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Rate
Time
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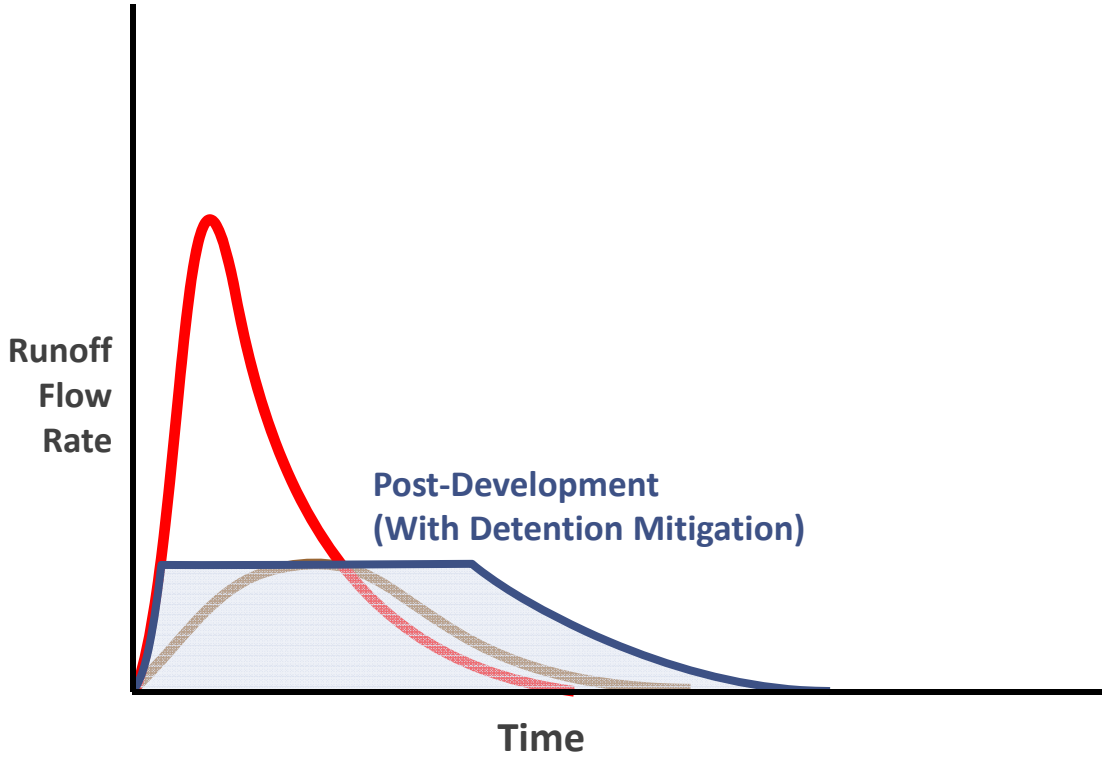
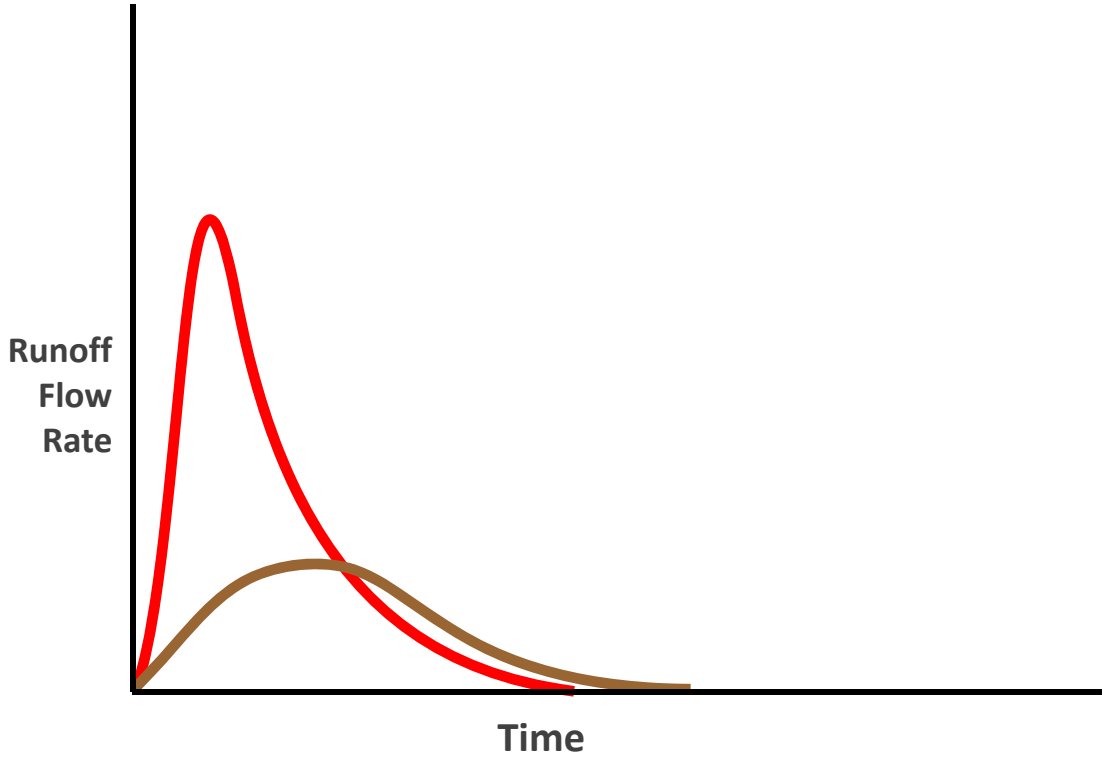
Required
Detention
Volume


Runoff
Flow
Rate
Post-Development
(With Detention Mitigation)
Time


Pre-Development
Runoff Volume
<
Post-Development
Runoff Volume
(With Detention Mitigation)


Runoff
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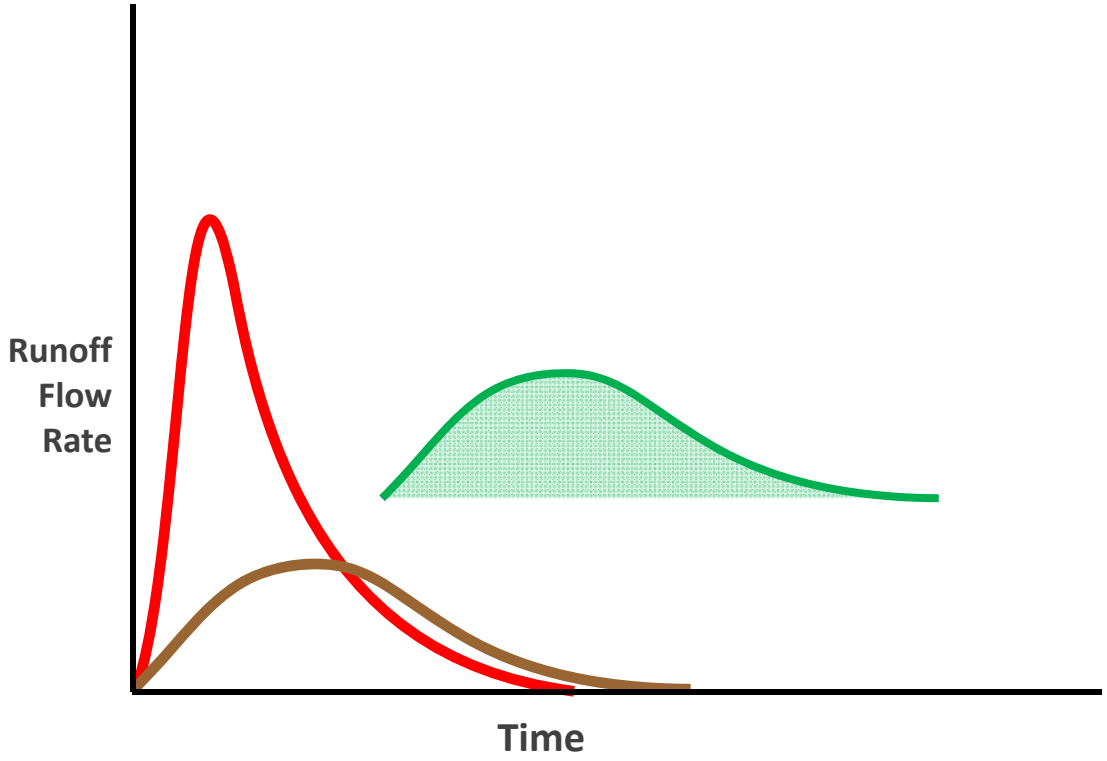
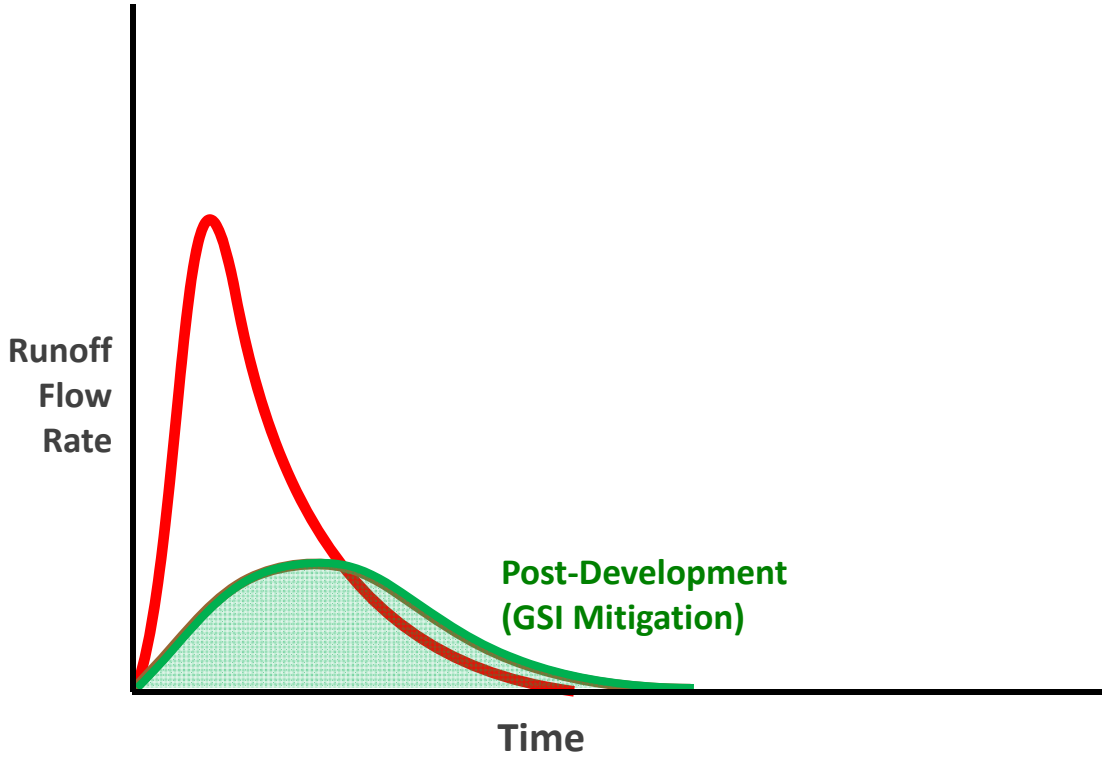
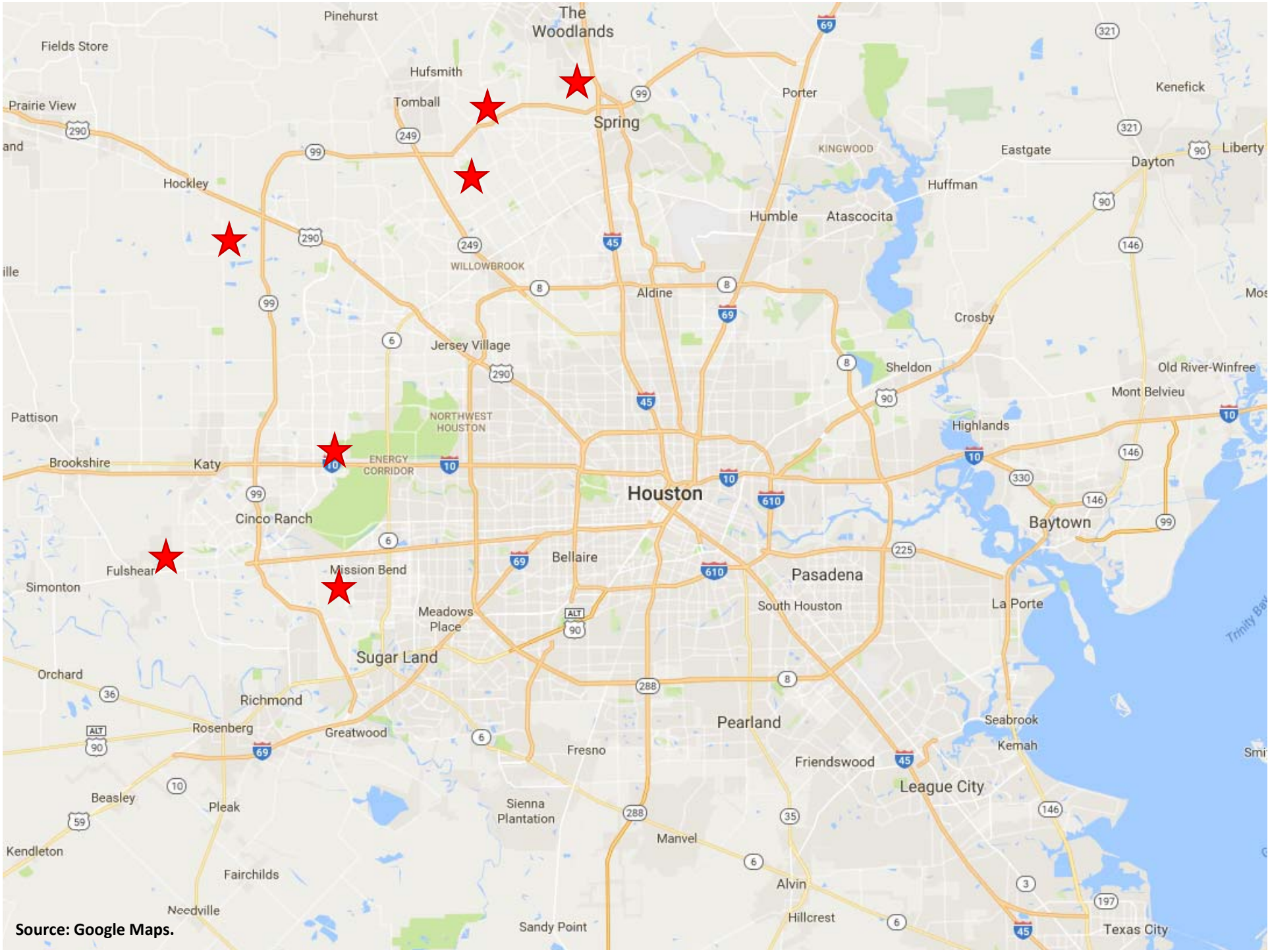

Runoff
Flow
Rate
Time


Runoff
Flow
Rate
Post-Development
(GSI Mitigation)
Time

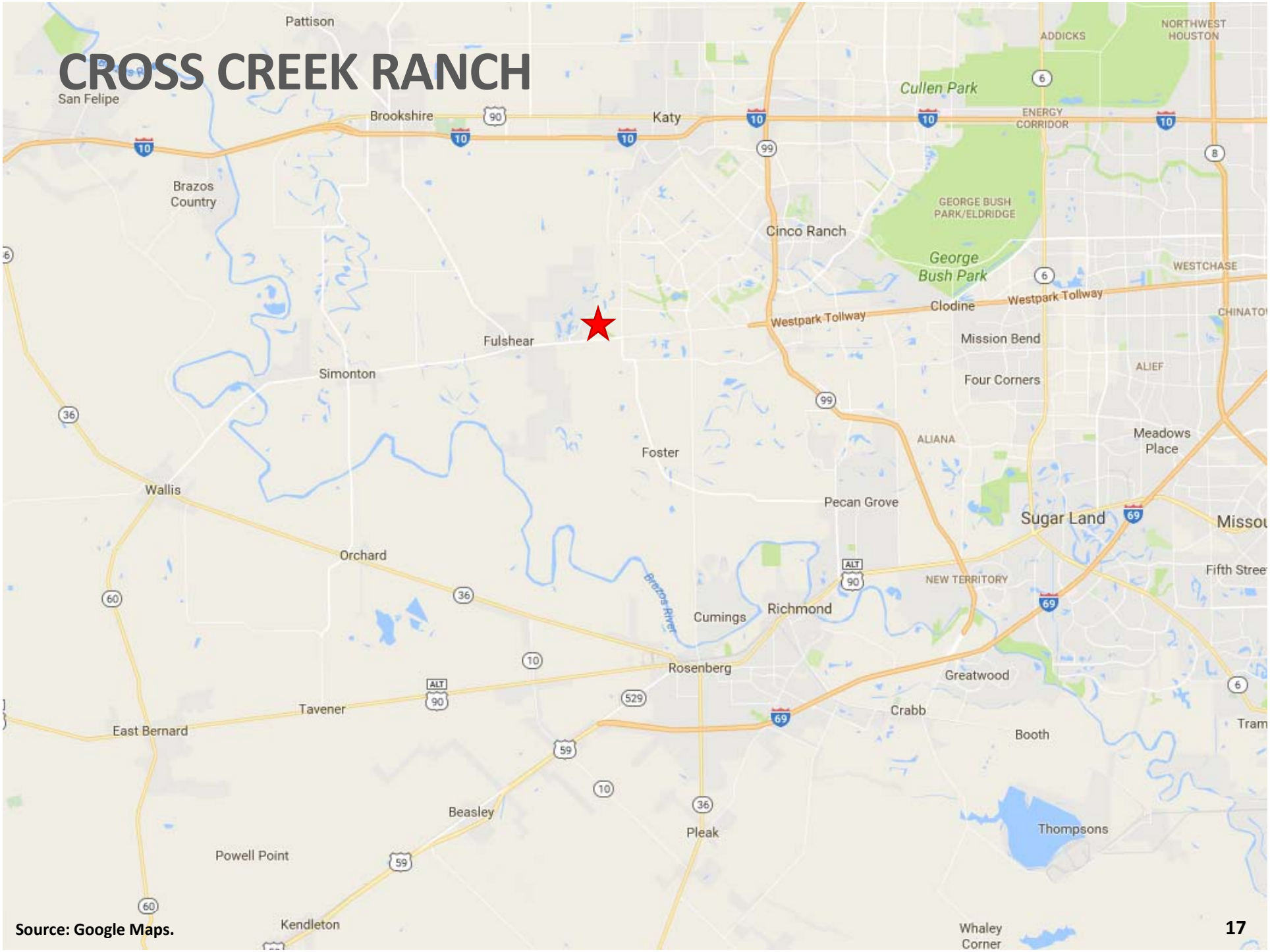

Pre-Development
Runoff Volume
=
Post-Development
Runoff Volume

HOUSTON AREA GREEN STORMWATER INFRASTRUCTURE PROJECTS



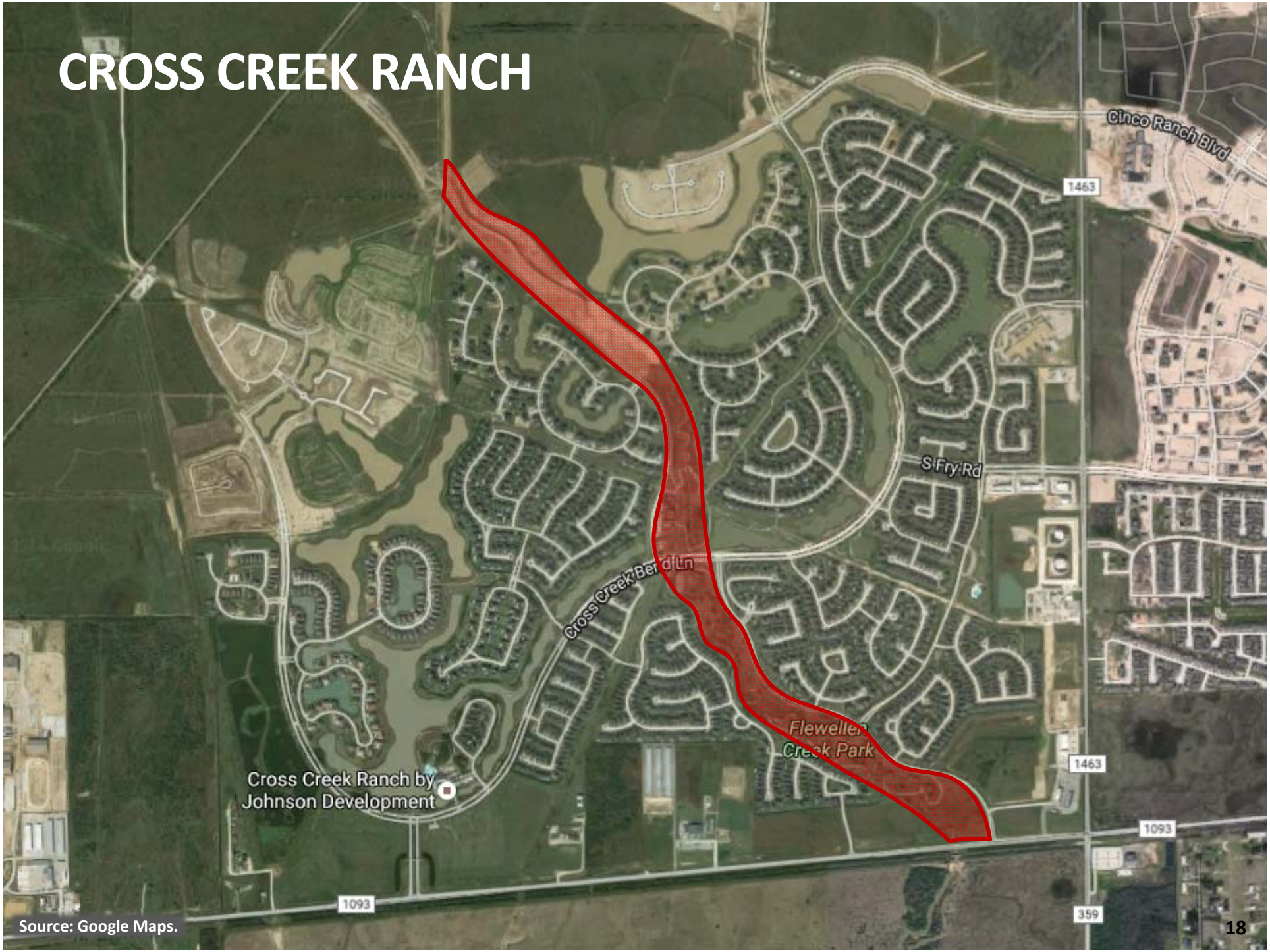
Source: Google Maps.

CROSS CREEK RANCH



Source: Google Maps.

CROSS CREEK RANCH



Source: Google Maps.

CROSS CREEK RANCH

Owner: Johnson Development. Engineer: Brown & Gay. Photo Credit: M. Bloom

Owner: Johnson Development. Engineer: Brown & Gay. Photo Credit: M. Bloom

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Owner: Johnson Development. Engineer: Brown & Gay. Photo Credit: M. Bloom

AUDUBON GROVE, SPRINGWOODS VILLAGE

Source: Google Maps.

AUDUBON GROVE, SPRINGWOODS VILLAGE

Source: Google Maps.

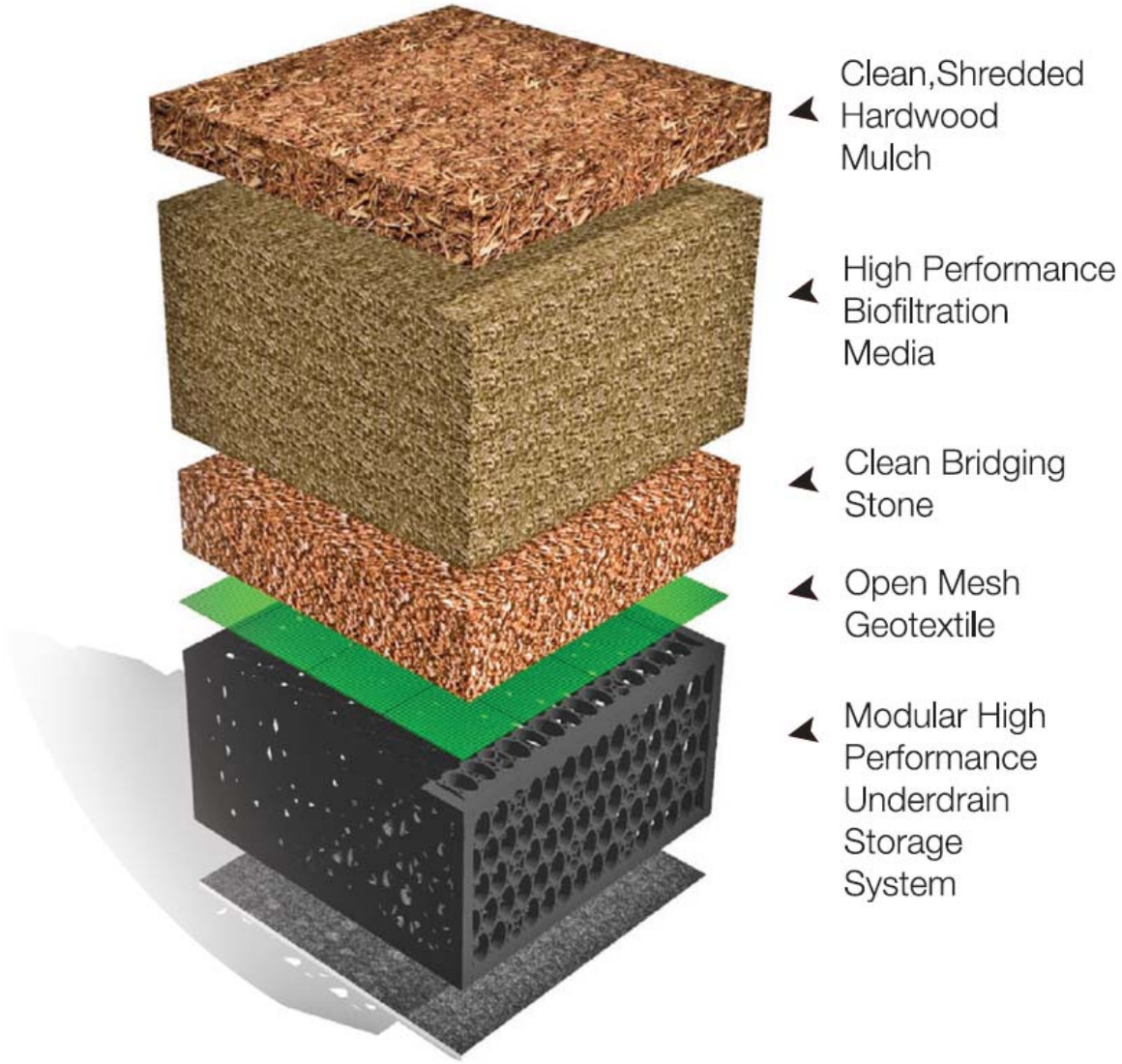
AUDUBON GROVE, SPRINGWOODS VILLAGE

Source: Taylor Morrison.

AUDUBON GROVE, SPRINGWOODS VILLAGE

Developer: Taylor Morrison. Engineer: Costello. Photo Credit: M. Bloom

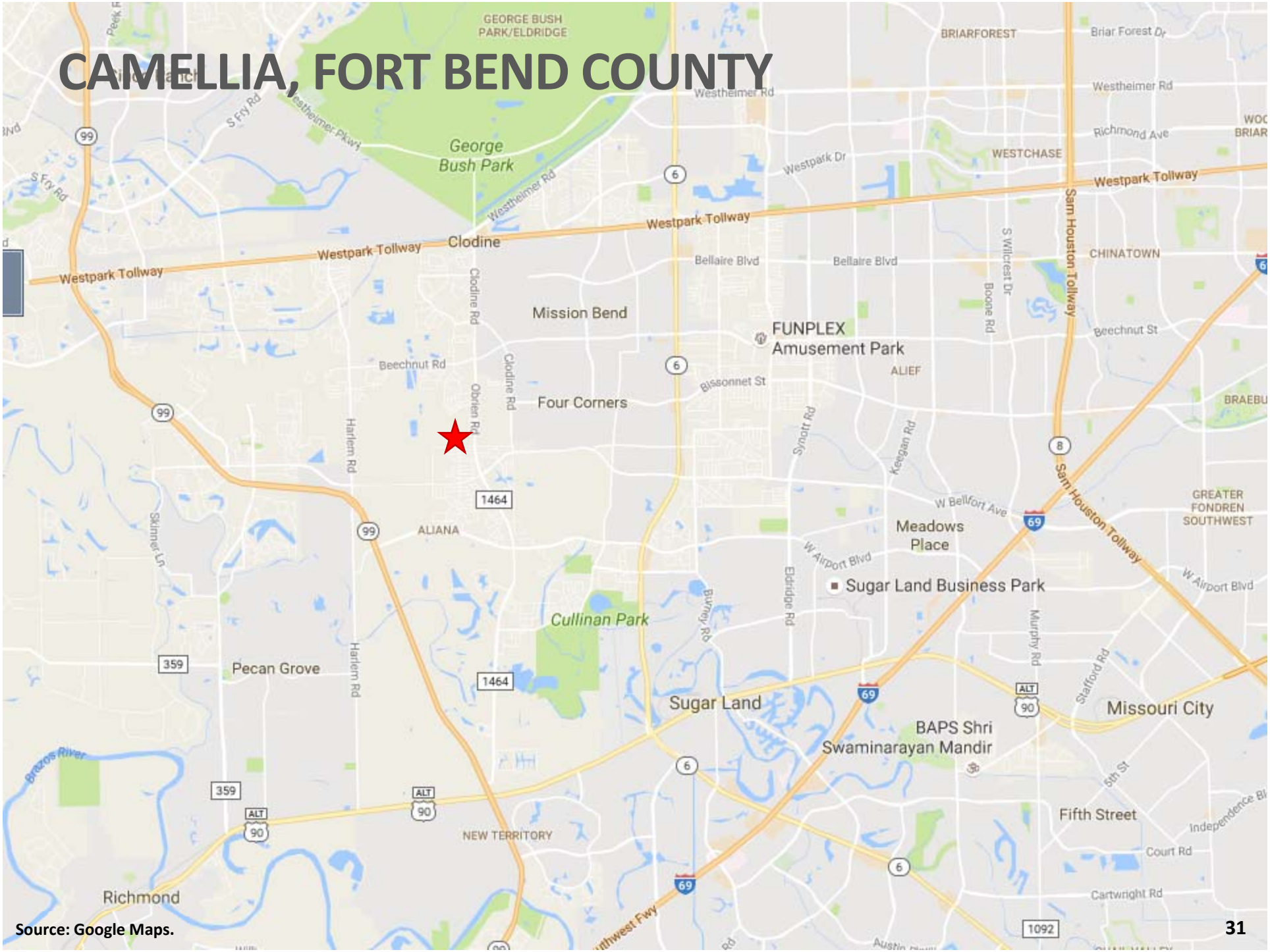
BIOFILTER / BIORETENTION CELL



SOURCE: Convergent Water Technologies, Inc.

Developer: Taylor Morrison. Engineer: Costello. Photo Credit: M. Bloom

CAMELLIA, FORT BEND COUNTY



Source: Google Maps.

CAMELLIA, FORT BEND COUNTY – TRADITIONAL LAND PLAN

Source: Ring, J. 2015. *Talking Dollars and Sense: LID Construction Costs.* Presented at the ASCE International LID Conference. Houston, Texas. January.

CAMELLIA, FORT BEND COUNTY – LID LAND PLAN

Lots = 50' x 110'
Lot Yield = 323

Source: Ring, J. 2015. *Talking Dollars and Sense: LID Construction Costs.* Presented at the ASCE International LID Conference. Houston, Texas. January.

CAMELLIA, FORT BEND COUNTY

Source: Google Maps.

CAMELLIA, FORT BEND COUNTY

Photo Credit: M. Bloom

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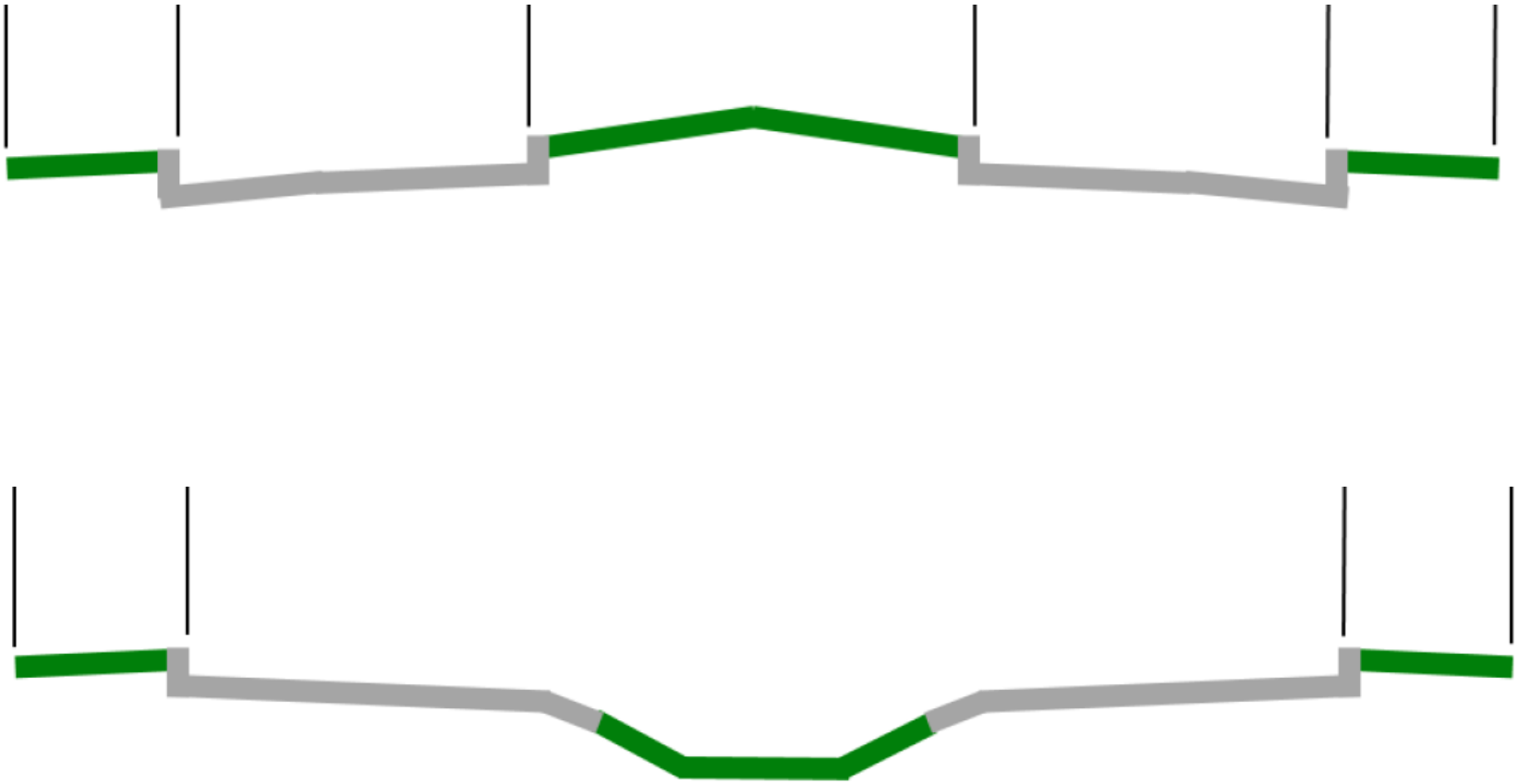
Photo Credit: M. Bloom

DEPRESSED MEDIAN

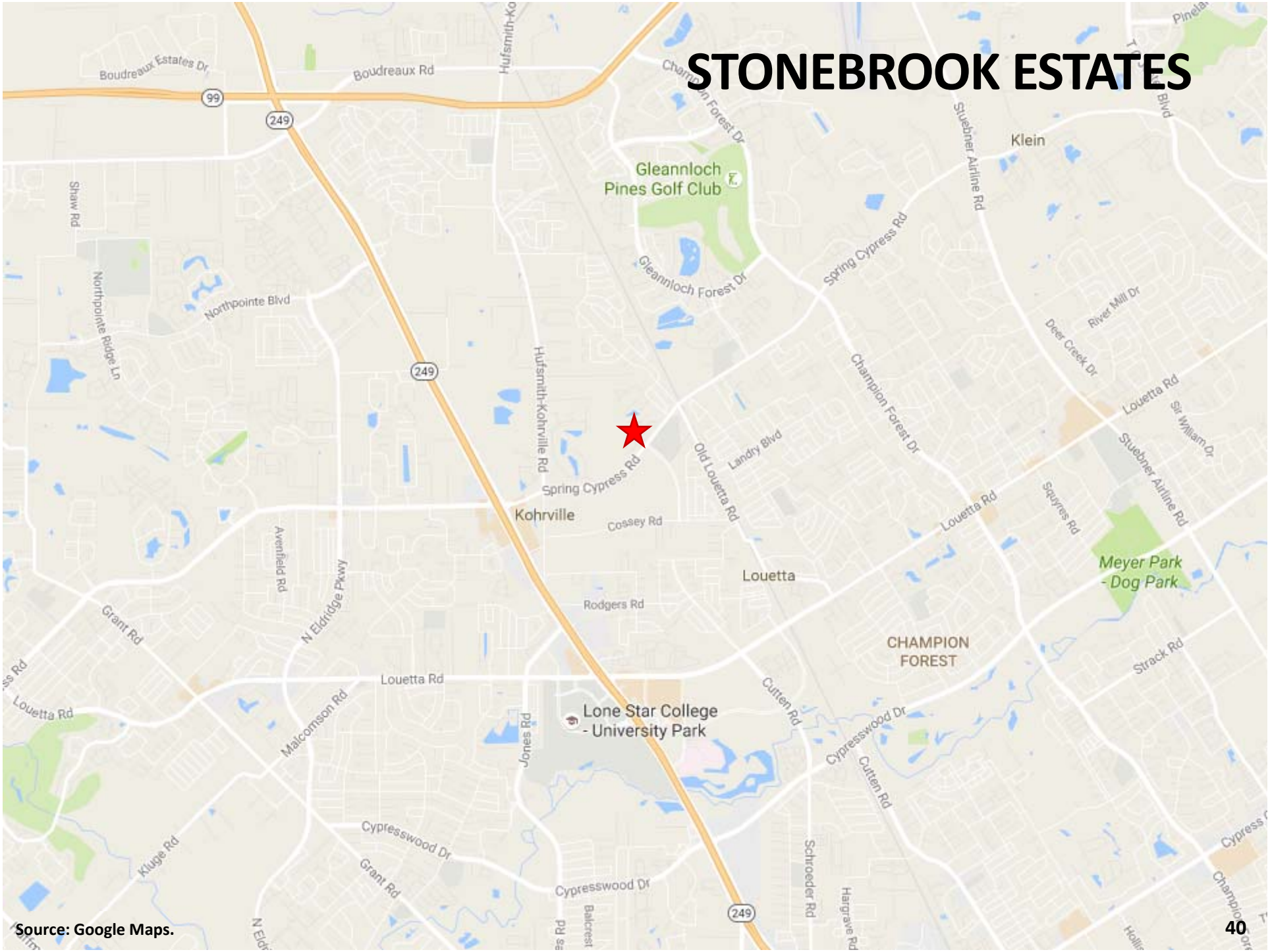


CAMELLIA, FORT BEND COUNTY

DRAINAGE SYSTEM ELEMENTS	TRADITIONAL	LOW IMPACT DEVELOPMENT	LID COST SAVINGS
Development Area	80 acres		
Storm Sewer	$449,000	$1,598,000	$1,149,000
Detention Basin	$296,000	NA	($296,000)
Irrigation System	NA	$248,000	$248,000
Amenity Basin	$2,875,000	NA	($2,875,000)
Landscaping for LID Features	NA	$31,000	$31,000
Storm Water Pollution Prevention	$85,000	$162,000	$77,000
TOTAL	$3,705,000	$2,039,000	($1,666,000)
Number of Lots	224	323	+ 99
Drainage System Cost Per Lot	$16,540	$6,313	($10,227)

Source: Ring, J. 2015. *Talking Dollars and Sense: LID Construction Costs.* Presented at the ASCE International LID Conference. Houston, Texas. January.

STONEBROOK ESTATES



Source: Google Maps.

Photo Credit: Terra Visions, LLC

STONEBROOK ESTATES

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STONEBROOK ESTATES

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STONEBROOK ESTATES

Source: Google Maps, design plans prepared by Aguirre & Fields, LP, and R. G. Miller Engineers, Inc.

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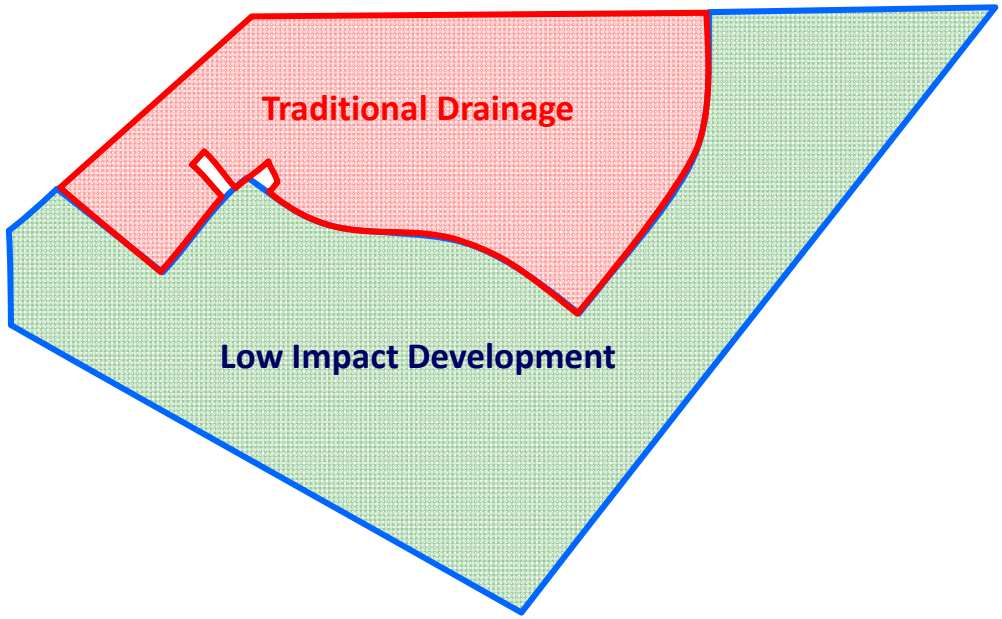
STONEBROOK ESTATES



	Traditional	LID	Combined
Area	19.03 acres	32.36 acres	51.4 acres
Detention Rate	0.55 ac-ft / ac	0.35 ac-ft / ac	0.42 ac-ft / ac

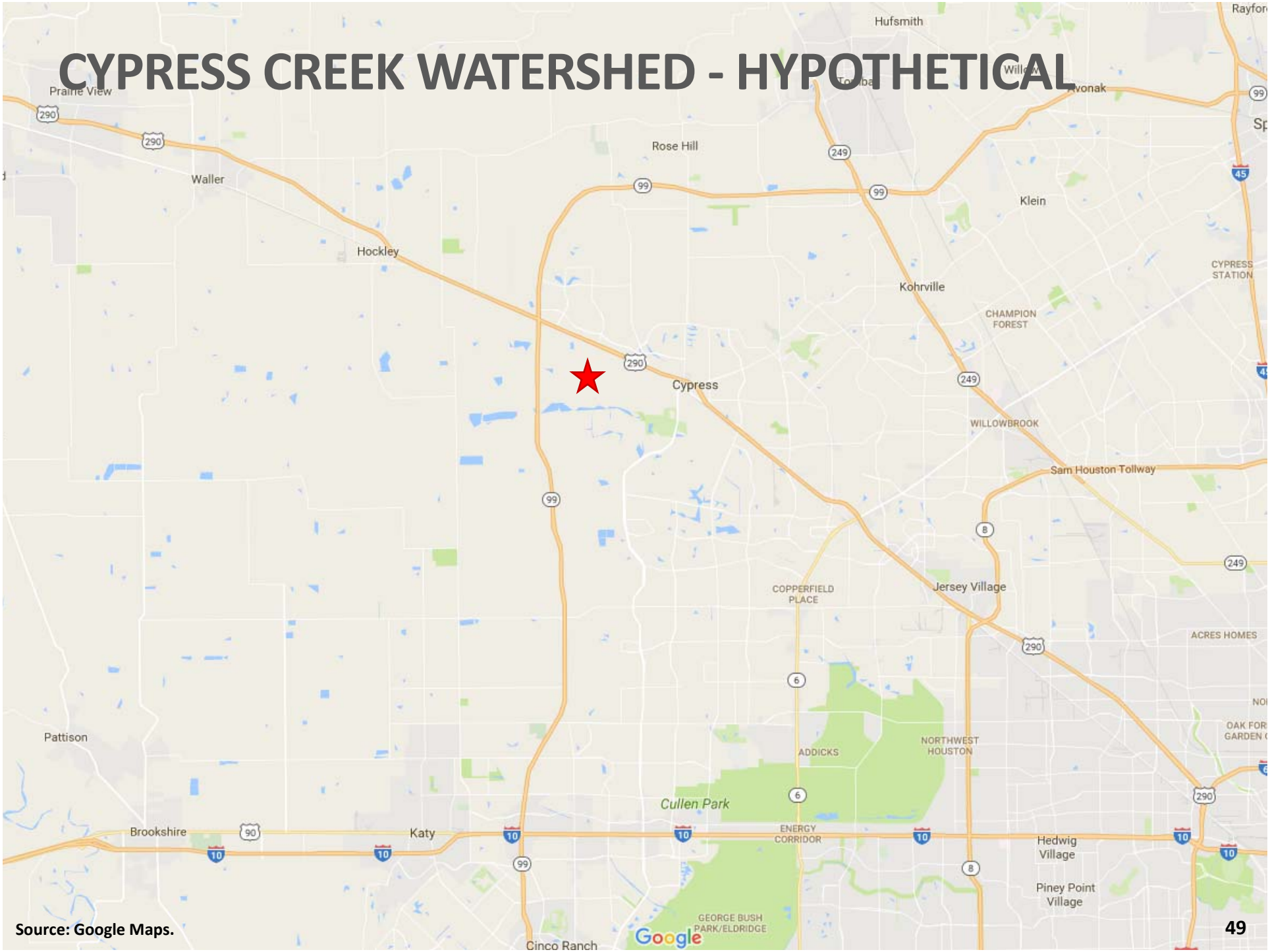
Source: Design plans prepared by Aguirre & Fields, LP and R. G. Miller Engineers, Inc.

STONEBROOK ESTATES

DRAINAGE SYSTEM ELEMENTS	HYBRID DEVELOPMENT
Development Area	51.4 acres
Total Number of Lots	135
Storm Sewer and Bioswales	$675,000
Detention Basin	$213,000
Storm Water Pollution Prevention	$7,000
TOTAL	$895,000
Number of LID Lots	92 (68%)
Number of Traditional Lots	43 (32%)
Prorated Drainage System Cost Per LID Lot	$6,615 / lot
Prorated Drainage System Cost Per Traditional Lot	$6,660 / lot

Source: Bid tabulations. 2013.

CYPRESS CREEK WATERSHED - HYPOTHETICAL

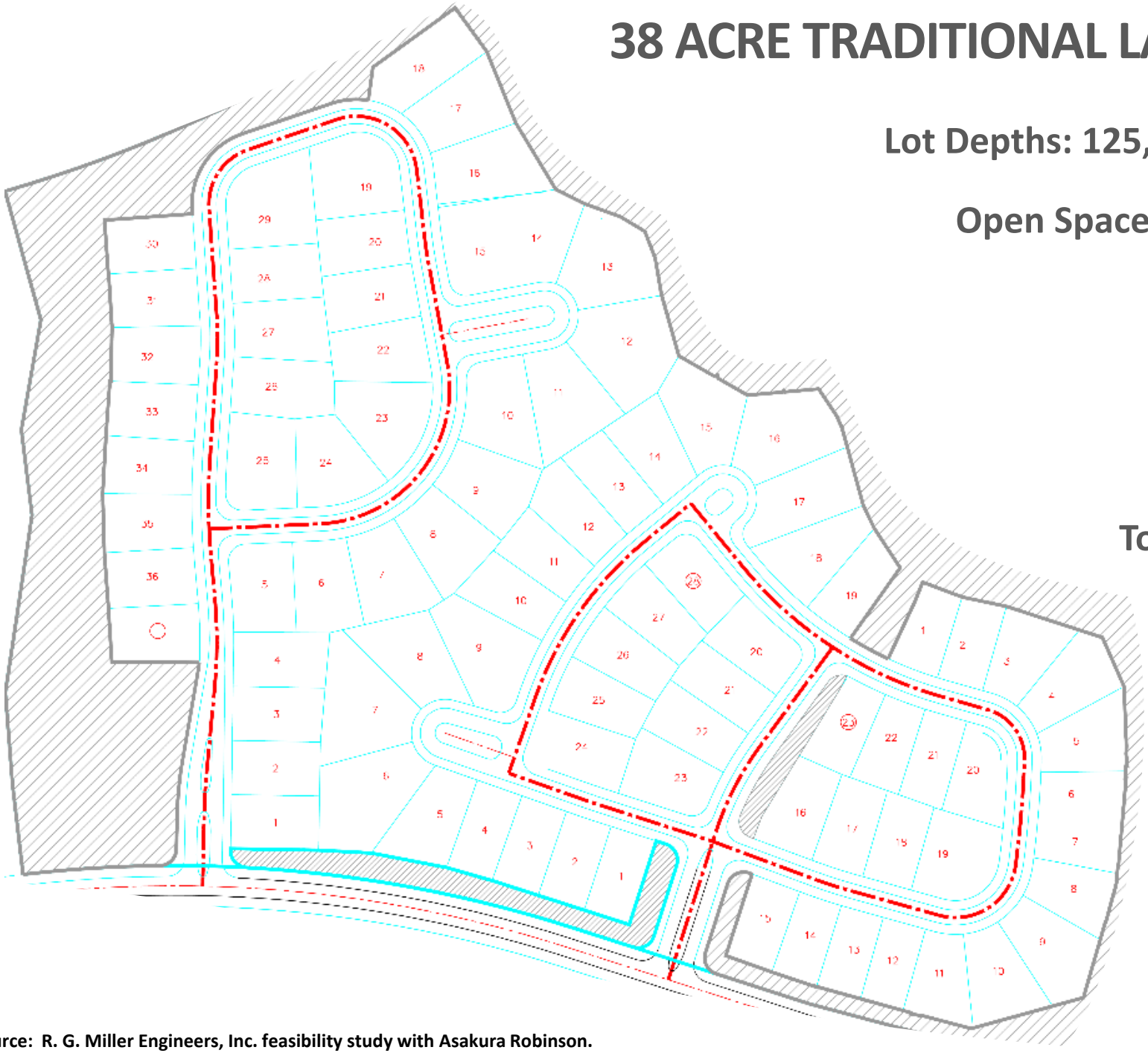


Source: Google Maps.

TRADITIONAL CROSS SECTION

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

38 ACRE TRADITIONAL LAND PLAN



Lot Depths: 125, 130, 135 ft

Open Space: 7.95 acres

65’ Lots: 23

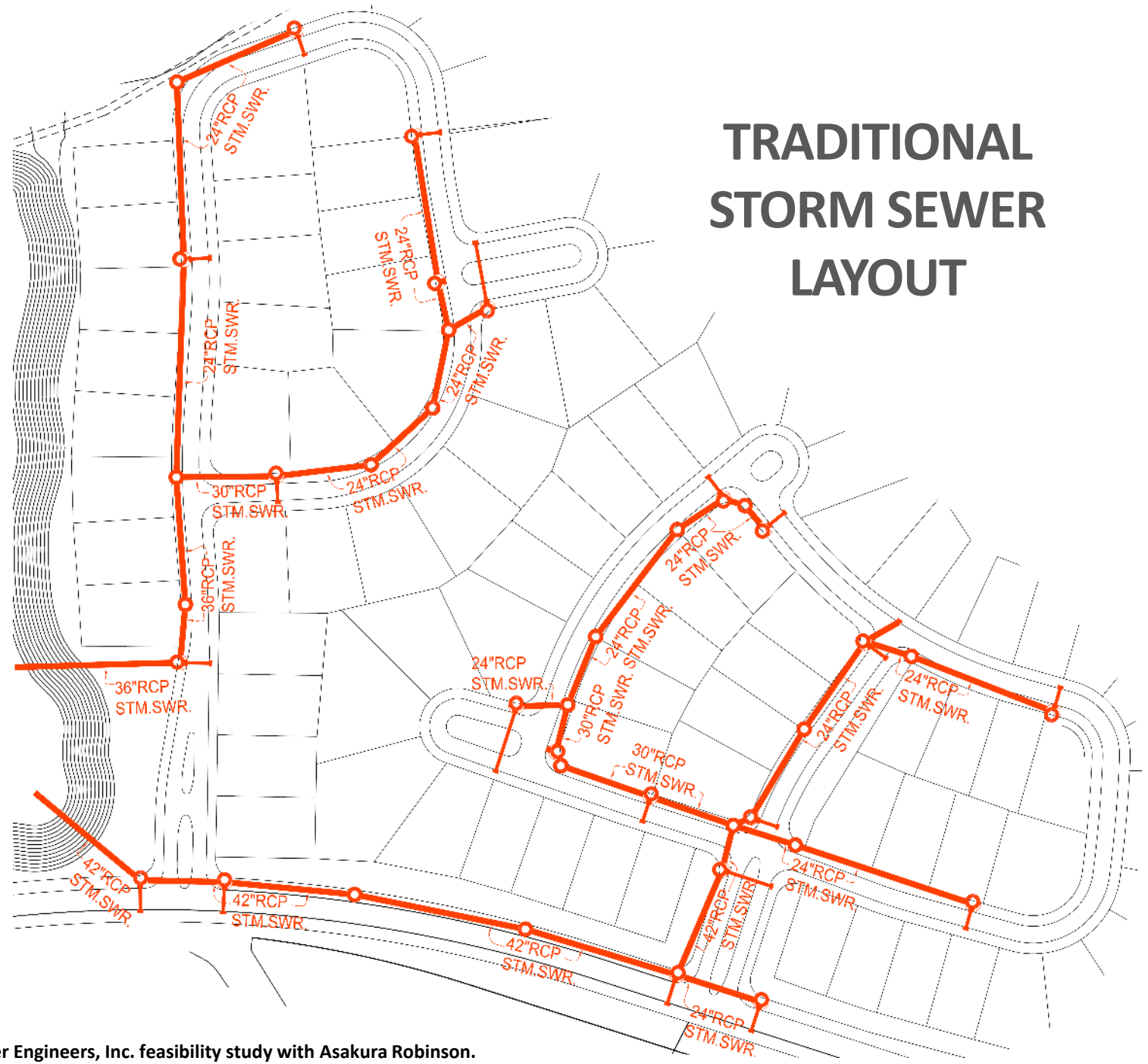
70’ Lots: 28

80’ Lots: 37

Total Lots: 88

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

TRADITIONAL STORM SEWER LAYOUT



Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

TRADITIONAL DESIGN - DEVELOPER AMENITY ITEMS					
No.	Description	Unit	Quantity	Unit Price	Amount
1.	Amenity Lake Earthwork, Includes Excavation, Grading & Shaping of Amenity to Proposed Lines and Grades; Complete in Place	C.Y.	20,250	$3.50	$70,875
2.	2' Clay Liner; Import And Placement; Complete in Place	C.Y.	4,150	$2.75	$11,413
3.	Engineered Fill; Complete In Place	C.Y.	16,100	$2.00	$32,200
				TOTAL AMENITY ITEMS	$114,488

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson. Costs updated August 2016.

TRADITIONAL DESIGN – DISTRICT ITEMS					
No.	Description	Unit	Quantity	Unit Price	Amount
1.	Detention Basin Earthwork, Includes Excavation, Grading & Shaping Of Basin To Proposed Lines & Grades; Complete in Place	C.Y.	40,000	$3.00	$120,000
2.	Engineering Fill; Complete in Place	C.Y.	40,000	$1.50	$60,000
3.	Turf Establishment; Complete In Place	Acre	5	$3,500	$17,500
4.	42" R.C.P. Storm Sewer, Includes Cement Stabilized Bedding and Backfill; Complete in Place	L.F.	1,160	$85	$98,600
5.	36" R.C.P. Storm Sewer Includes Cement Stabilized Bedding and Backfill; Complete in Place	L.F.	460	$75	$34,500
6.	30" R.C.P. Storm Sewer Includes Cement Stabilized Bedding and Backfill; Complete in Place	L.F.	430	$65	$27,950
7.	24" R.C.P. Storm Sewer Includes Cement Stabilized Bedding and Backfill; Complete in Place	L.F.	2,840	$50	$142,000
8.	24" R.C.P. Storm Sewer Lead, Includes Cement Stabilized Bedding and Backfill; Complete in Place	L.F.	810	$55	$44,550
9.	Type "C" Manhole (42" And Smaller); Complete in Place	EACH	39	$2,500	$97,500
10.	Type "H-2" Inlet; Complete in Place	EACH	19	$1,500	$28,500
11.	Trench Safety System For Storm Sewer Construction	L.F.	5,700	$1.00	$5,700
				TOTAL DISTRICT ITEMS	$676,800
				GRAND TOTAL	$791,288

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson. Costs updated August 2016.

NATURAL DRAINAGE CROSS SECTION

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

“CROSS SWALE” CROSS SECTION

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

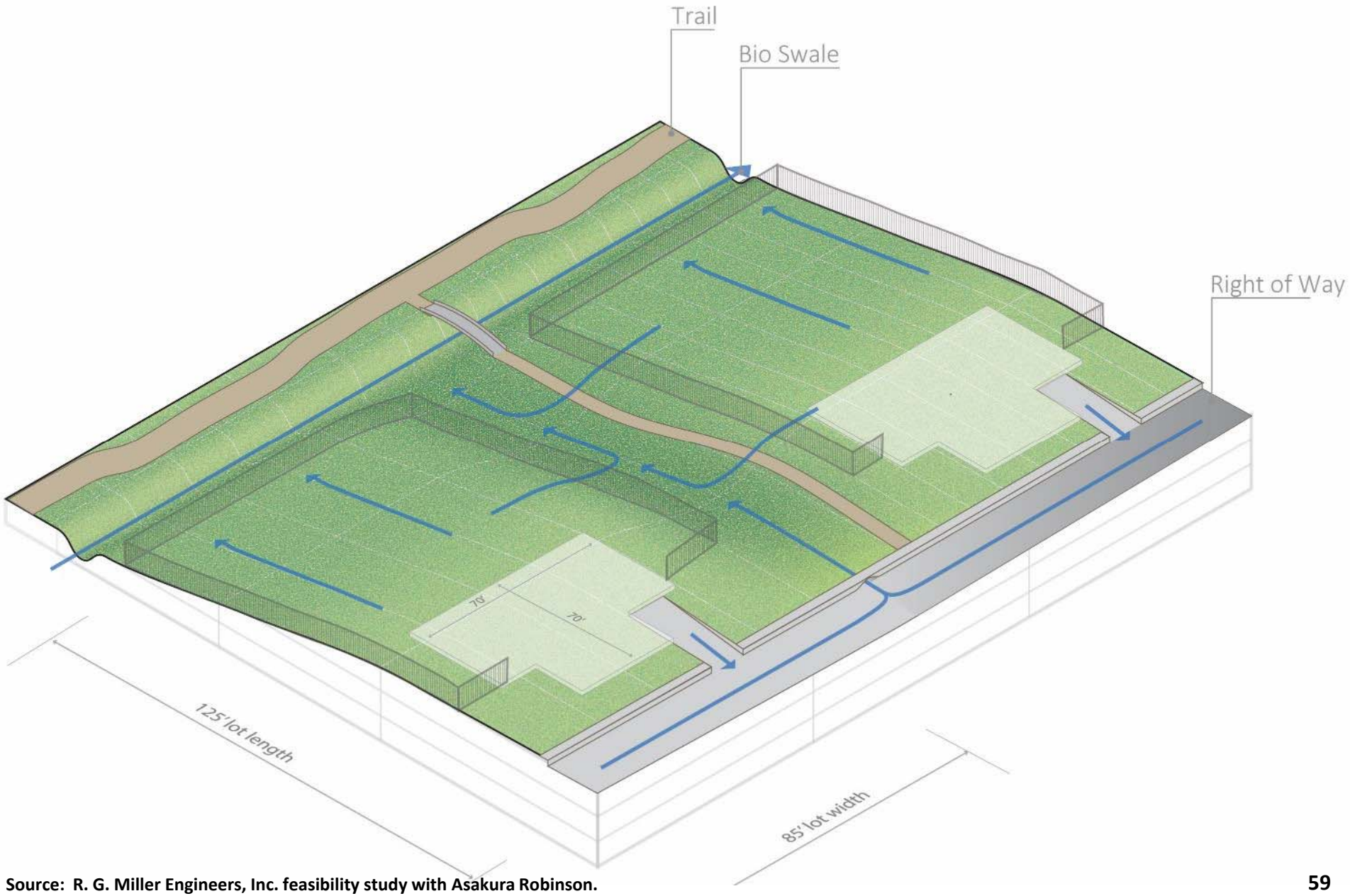
SINGLE, CROSS-SLOPE PAVING

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

“FALSE BACK” INLETS

Photo credits: M. Bloom

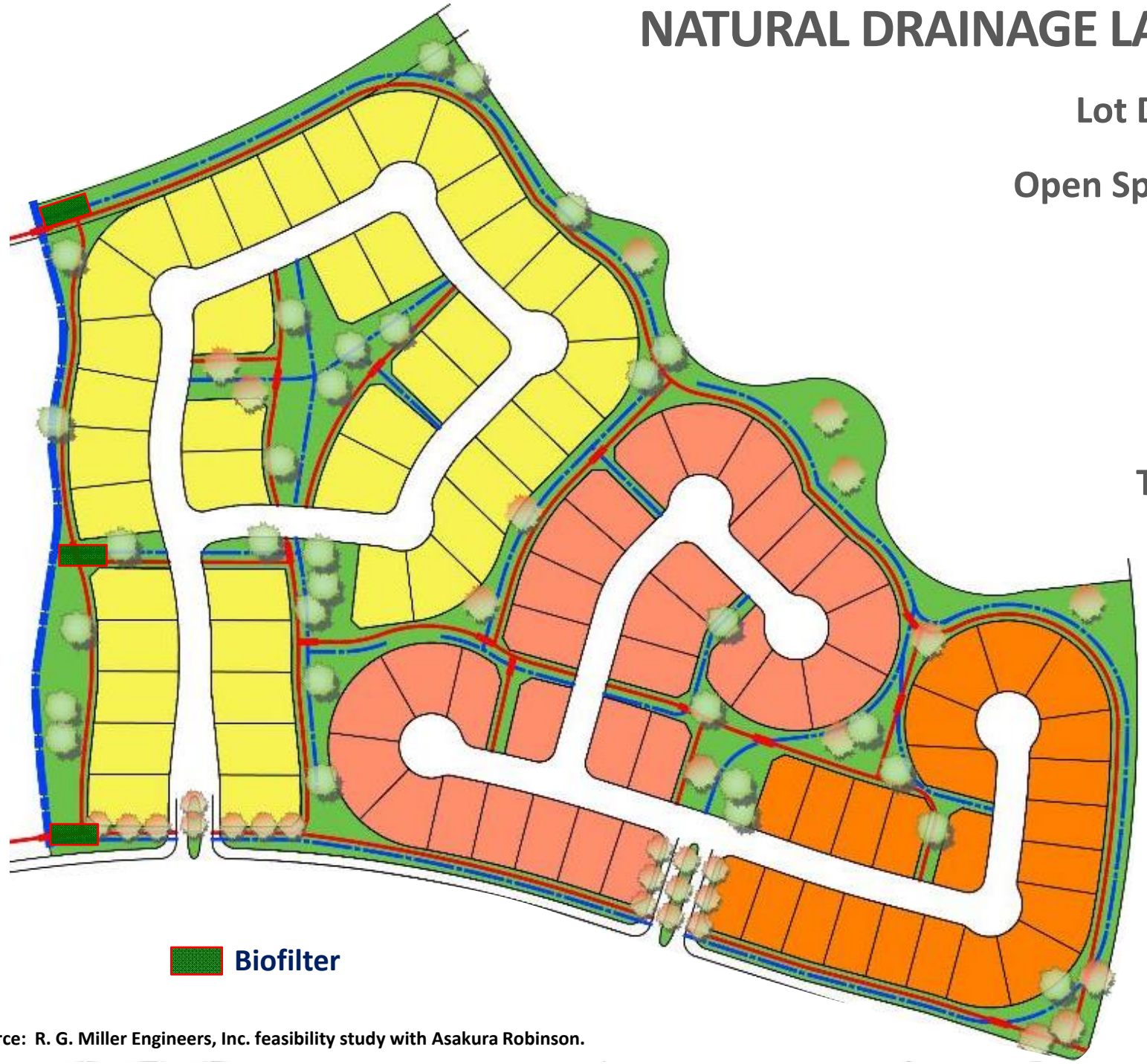
NATURAL DRAINAGE OPTION



Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

NATURAL DRAINAGE LAND PLAN



Lot Depth: 125 ft

Open Space: 11.5 ac

65’ Lots: 23

70’ Lots: 30

80’ Lots: 42

Total Lots: 95

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson.

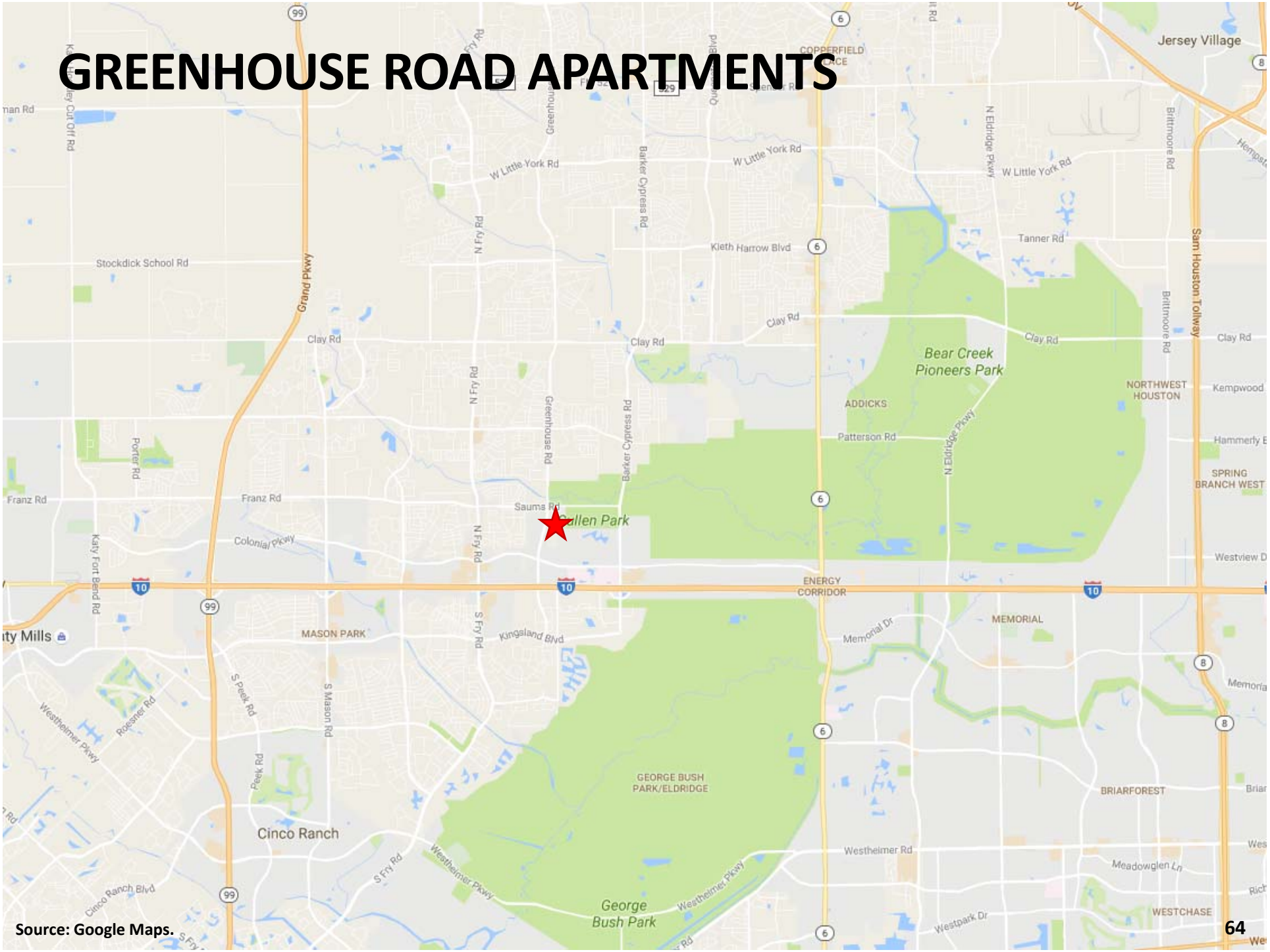
No.	Description	Unit	Quantity	Unit Price	Amount
1.	48" RCP Storm Sewer Culvert, Includes Cement Stabilized Sand Bedding And Backfill; Complete In Place	L.F.	400	$125	$50,000
2.	"False Back" Curb Inlet, Includes Cement Stabilized Sand Bedding and Backfill; Complete In Place	EACH	15	$1,200	$18,000
3.	West Side Channel Earthwork, Includes Excavation, Grading & Shaping Of Channel To Proposed Lines & Grades; Complete in Place	C.Y.	5,333	$3.00	$15,999
4.	High Performance Biofiltration System and Related Earthwork; All Inclusive; Complete In Place	EACH	3	$38,000	$114,000
5.	Drainage Swale (3:1 SS, 4' Bottom, 4' Depth); Seeded and Mulched, Complete In Place	L.F.	8,300	$5.00	$41,500
6.	Landscaping; Includes Trees, Shrubs, Native Grass Along Swale System; Complete In Place	Acre	8.2	$24,000	$196,800
7.	Trench Safety System For Storm Sewer Construction; Complete In Place	L.F.	400	$1.50	$600
				TOTAL	$436,899

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson. Costs updated August 2016.

	TRADITIONAL	LOW IMPACT DEVELOPMENT	DIFFERENCE
Tract Size (acres)	38	38	0
Open Space (acres)	7.95	11.46	3.51
Lot Depth (feet)	130 (ave)	125	(5)
65’ Wide Lots	23	23	0
70’ Wide Lots	28	30	2
80’ Wide Lots	37	42	5
Total Lots	88	95	7
Number of Lots Next To Amenity Feature	8	95	87
Drainage System Cost	$791,288	$436,899	($)
Drainage System Cost Per Lot	$8,992 each	$4,599 each	($4,393 each)

Source: R. G. Miller Engineers, Inc. feasibility study with Asakura Robinson. Costs updated August 2016.

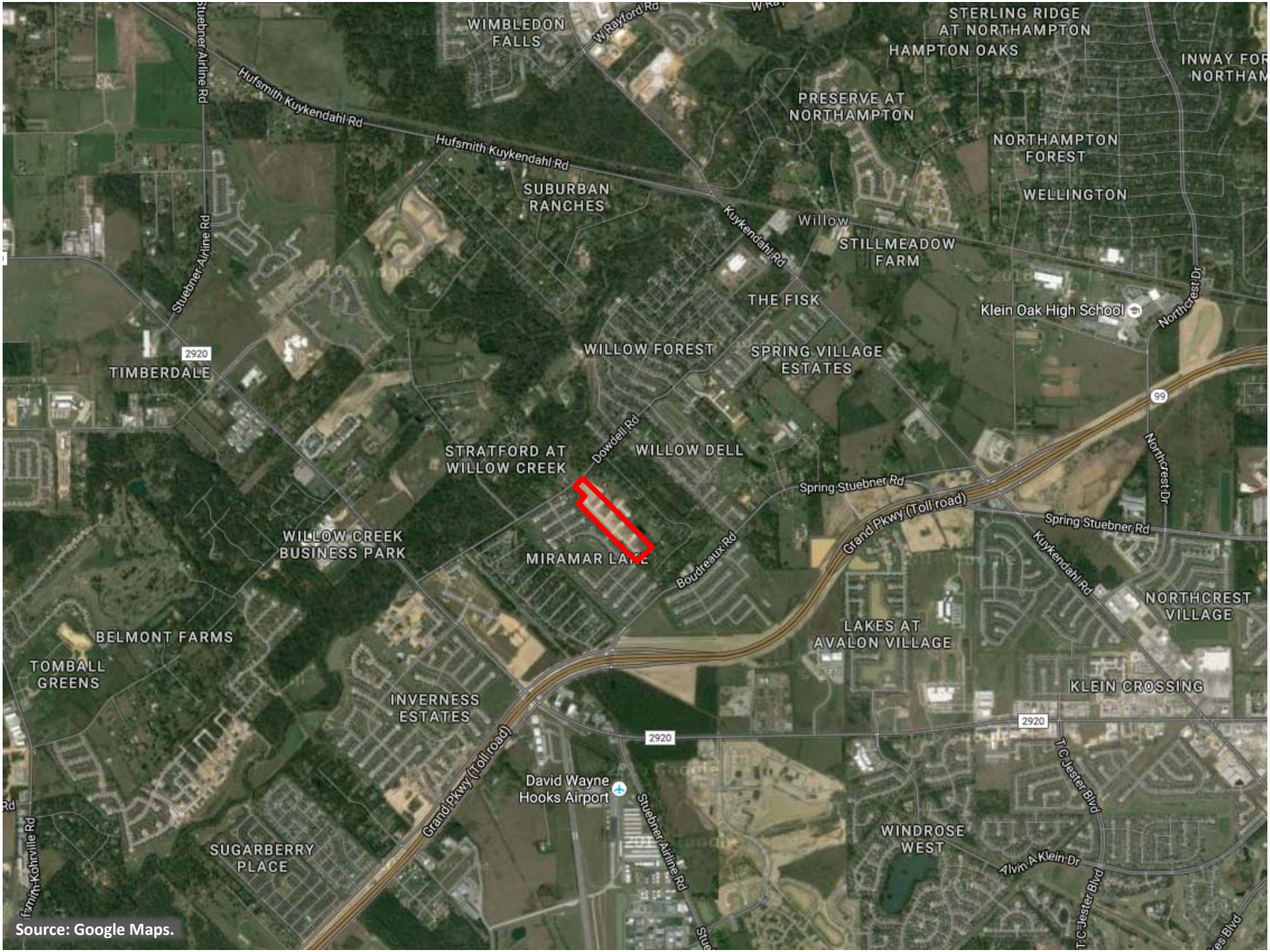
GREENHOUSE ROAD APARTMENTS



Source: Google Maps.

DOWDELL ROAD, KLIEN

Source: Google Maps.

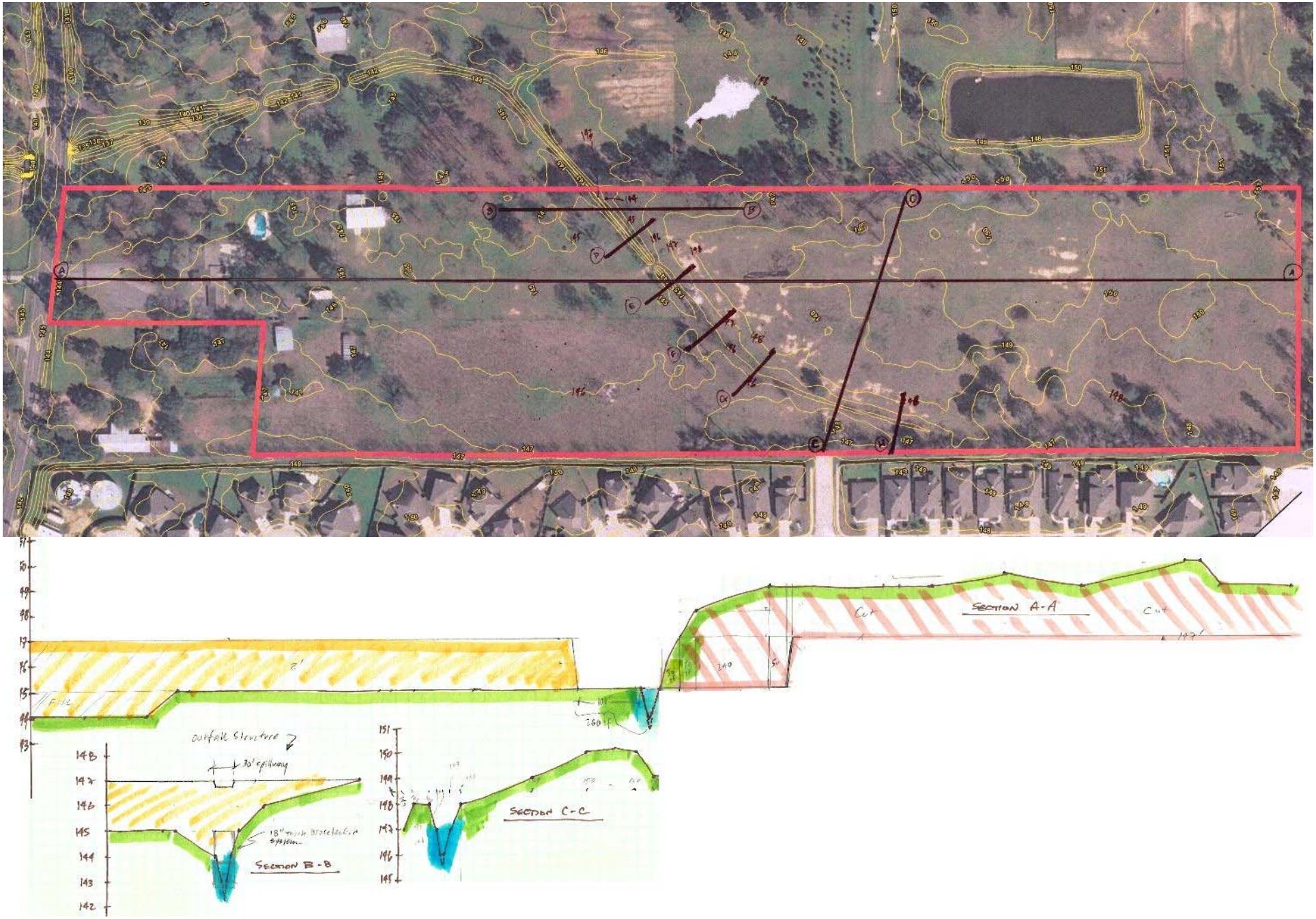


Source: Google Maps.

DOWDELL ROAD - TRADITIONAL

- Pumped detention
- Detention rate is 1 ac-ft/ac
- Wetland impacts

Source: Jones & Carter, Schematic Plan, 2014.



Source: R. G. Miller Engineers, Inc. 2014 Feasibility Study.

DOWDELL ROAD - LID

Source: R. G. Miller Engineers, Inc. 2014 Feasibility Study.

DOWDELL ROAD SUMMARY

	TRADITIONAL	LOW IMPACT DEVELOPMENT	DIFFERENCE
Tract Size (acres)	19	19	0
Lot Depth (feet)	120	120	0
Number of Lots	57	58	+ 1
Number of Lots Next To Amenity Feature	16	58	+ 42
Detention Basin Cost	$545,740	$131,680	- $414,060
Drainage System Costs	$356,750	$249,850	- $106,900
Drainage System Cost Per Lot	$15,833	$6,578	- $9,255

Source: R. G. Miller Engineers, Inc. 2014 Feasibility Study.

APPLICABLE CRITERIA

Harris County Low Impact Development & Green Infrastructure Design Criteria for Storm Water Management

Submitted by: Arthur L. Storey, Jr., P.E.
Executive Director, Public Infrastructure Department

John Blount, P.E.
Director, Architecture & Engineering Division

Michael D. Talbott, P.E.
Director, Harris County Flood Control District

Adopted by Harris County Commissioners Court

Ed Emmett
County Judge

El Franco Lee
Commissioner, Precinct 1

Steve Radack
Commissioner, Precinct 3

Jack Morman
Commissioner, Precinct 2

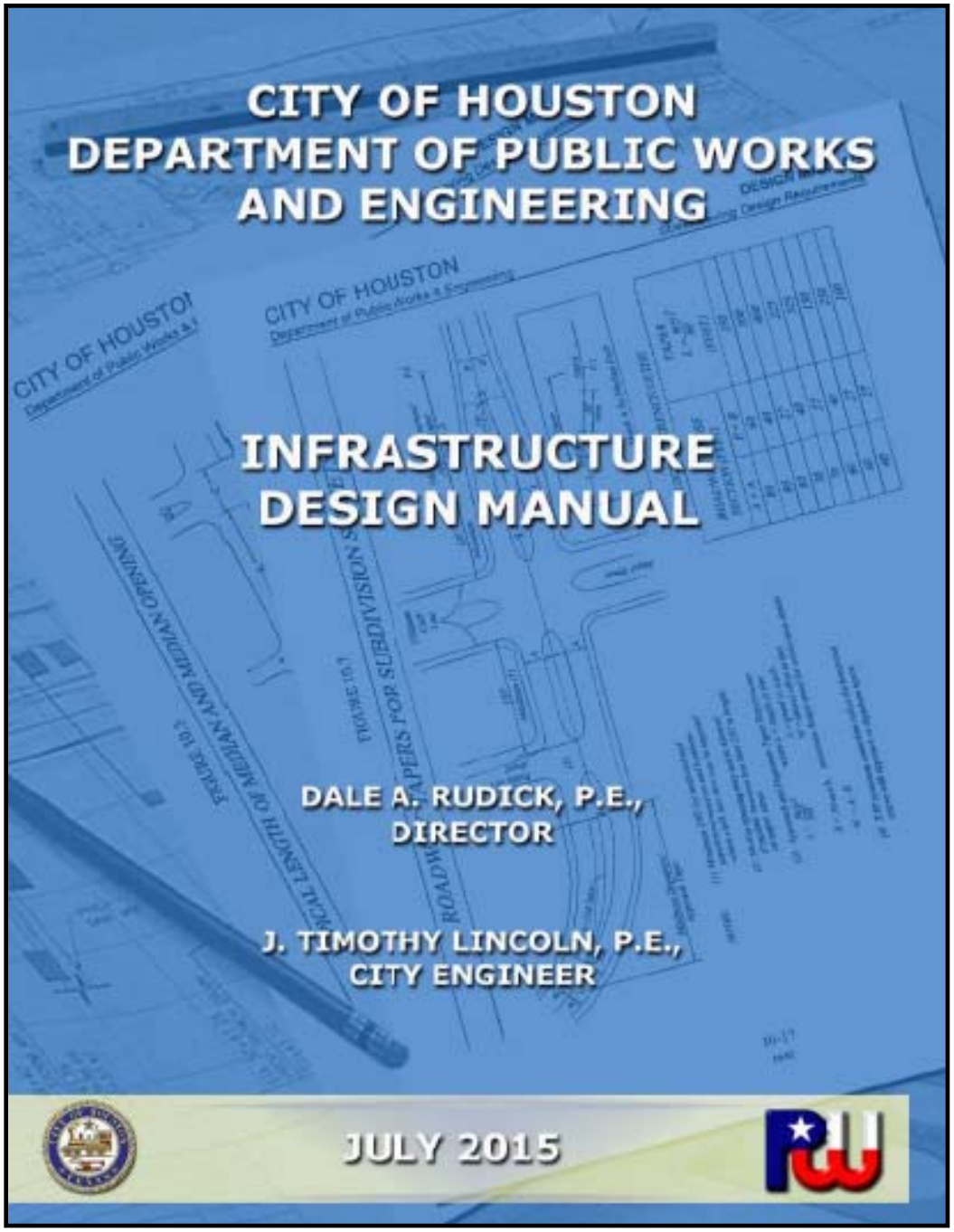
Jerry Eversole
Commissioner, Precinct 4

Adopted April 2011

HARRIS COUNTY DESIGN PROVISIONS

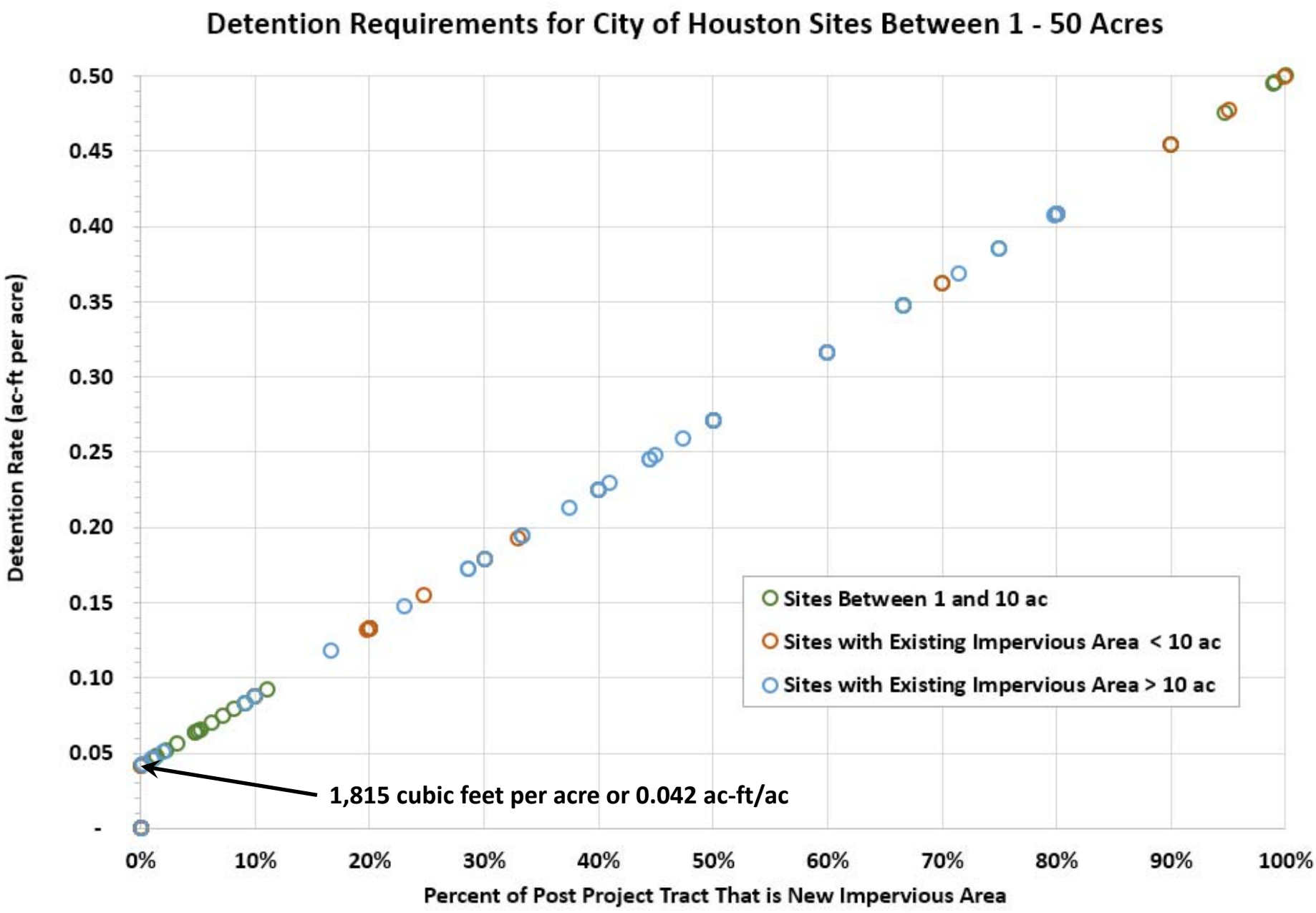
Requirement	Traditional	Low Impact Development
HCFCD Gravity Drained Detention	0.55 ac-ft/ac	0.35 ac-ft/ac minimum*
Detention for Gravity Flow to HC Roadside Ditch	0.75 to 1.0 ac-ft/ac	0.55 ac-ft/ac minimum
Detention for Gravity Flow to HC Storm Sewer	0.65 ac-ft/ac	50% of Required Rate
Peak Flows	Post-Project < Pre-Project	Post-Project < Pre-Project

* Lowest allowable, must be supported by drainage study.


CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS
AND ENGINEERING
INFRASTRUCTURE
DESIGN MANUAL
DALE A. RUDICK, P.E.,
DIRECTOR
J. TIMOTHY LINCOLN, P.E.,
CITY ENGINEER
JULY 2015

CITY OF HOUSTON DESIGN PROVISIONS

Requirement	Chapter 9 Traditional	Low Impact Development
Detention on < 1 ac Tracts	0.2 ac-ft per ac of new imp + 0.04 ac-ft per ac existing imp	*Requires same volume of detention. See Chapter 13 for ideas about how reduce new impervious area.*
Detention on 1 to 10 ac Tracts		
Detention on 10 to 50 ac Tracts	See curve on next slide.	
Detention on > 50 ac Tracts	As per HCFCD criteria	


Detention Requirements for City of Houston Sites Between 1 - 50 Acres
Detention Rate (ac-ft per acre)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
-
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Post Project Tract That is New Impervious Area
Sites Between 1 and 10 ac
Sites with Existing Impervious Area < 10 ac
Sites with Existing Impervious Area > 10 ac
1,815 cubic feet per acre or 0.042 ac-ft/ac

QUESTIONS?

Michael F. Bloom, P.E.,
ENV SP, CFM, BCEE
Sustainability Practice Manager

r.g. miller engineers

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