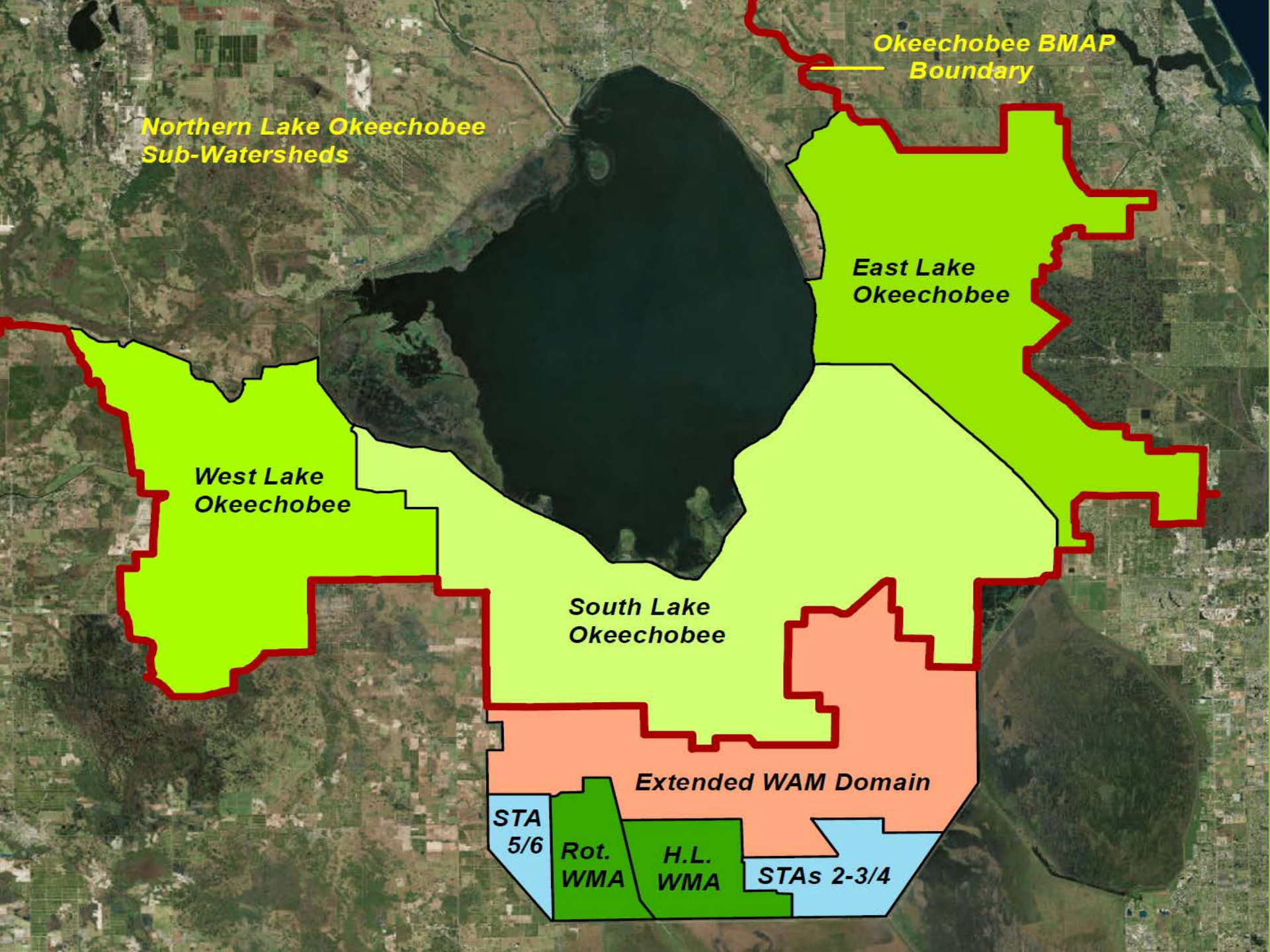
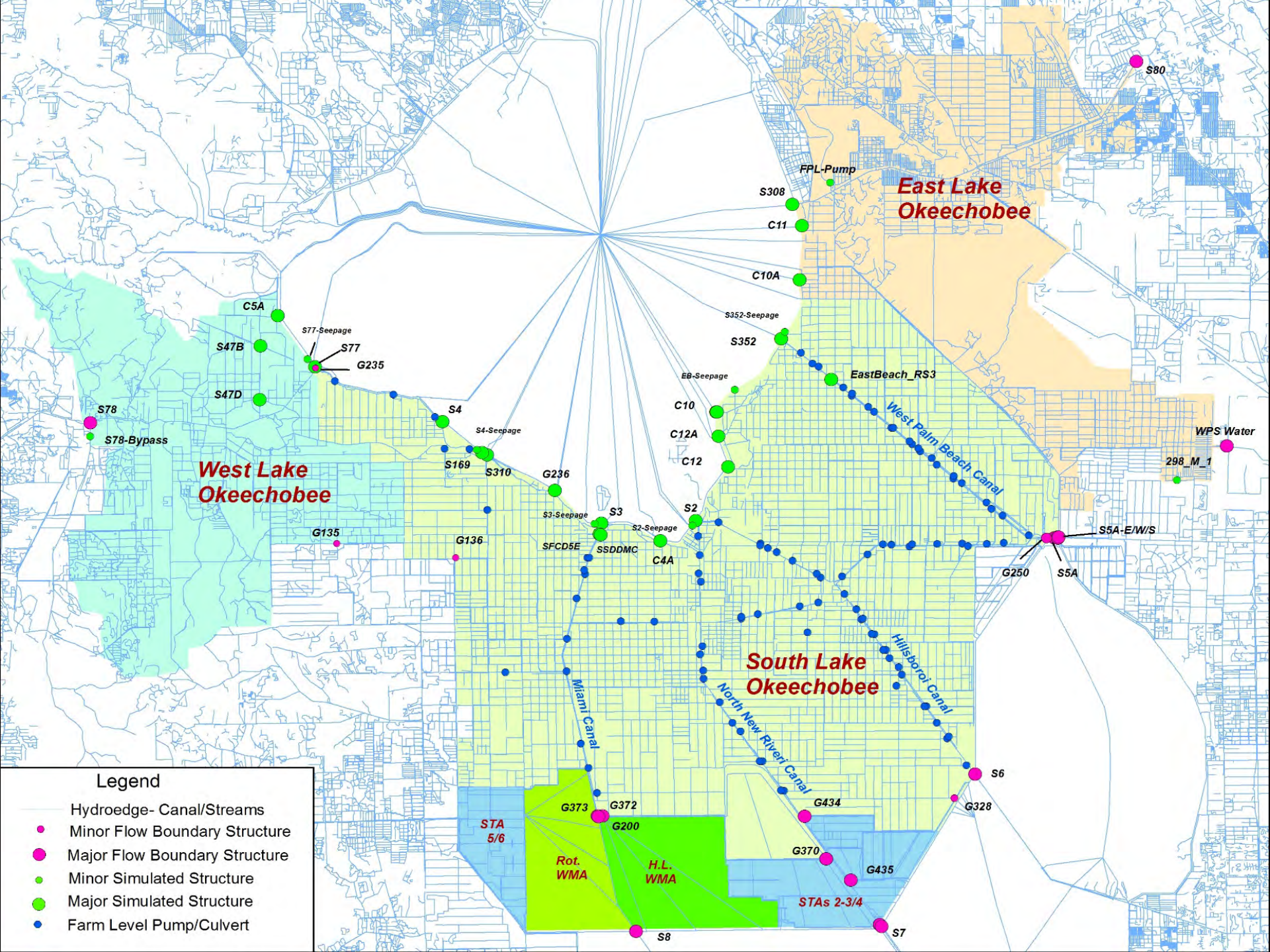
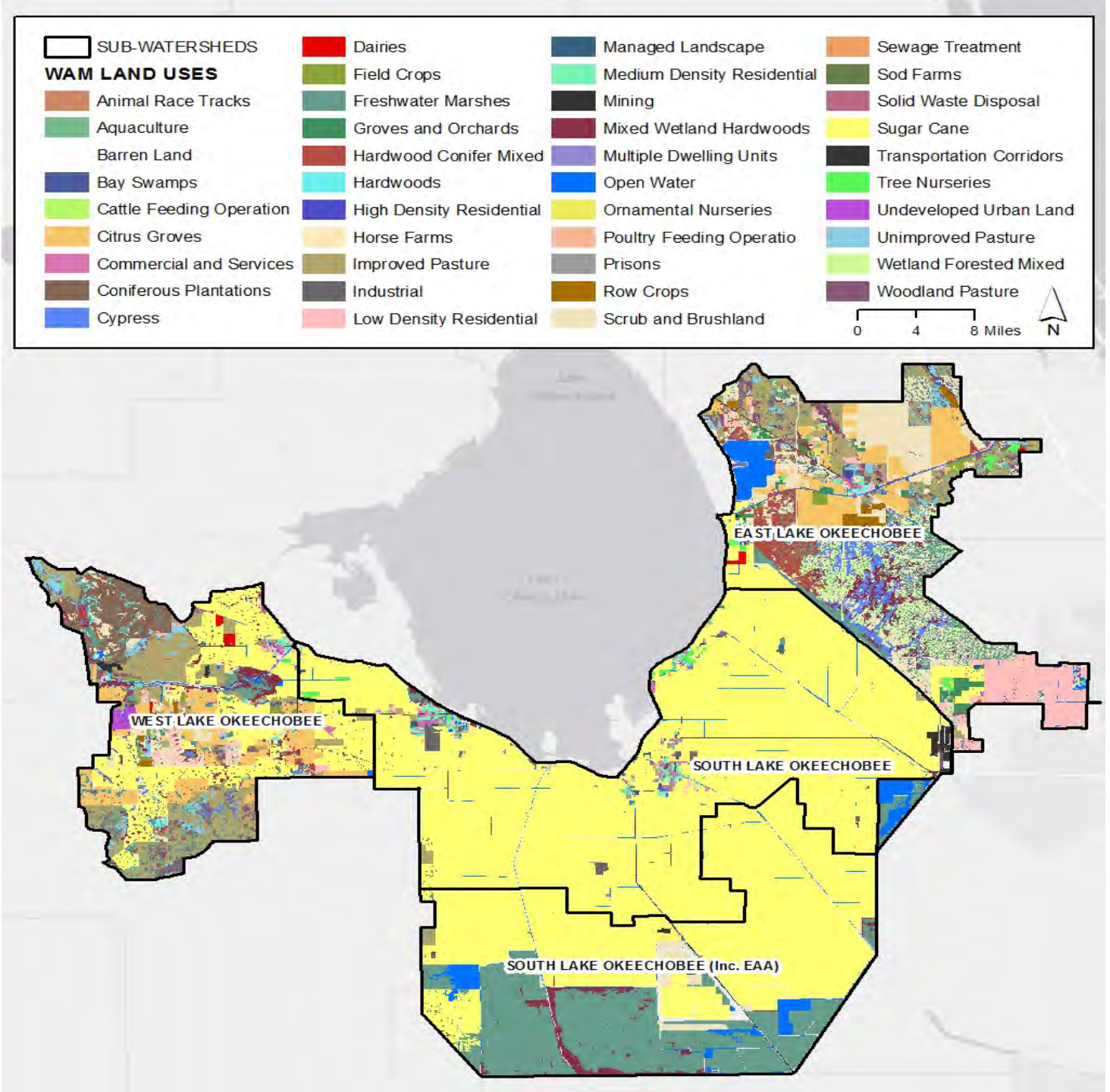
Simulations Conducted with WAM for the Southern Lake Okeechobee Sub-watersheds

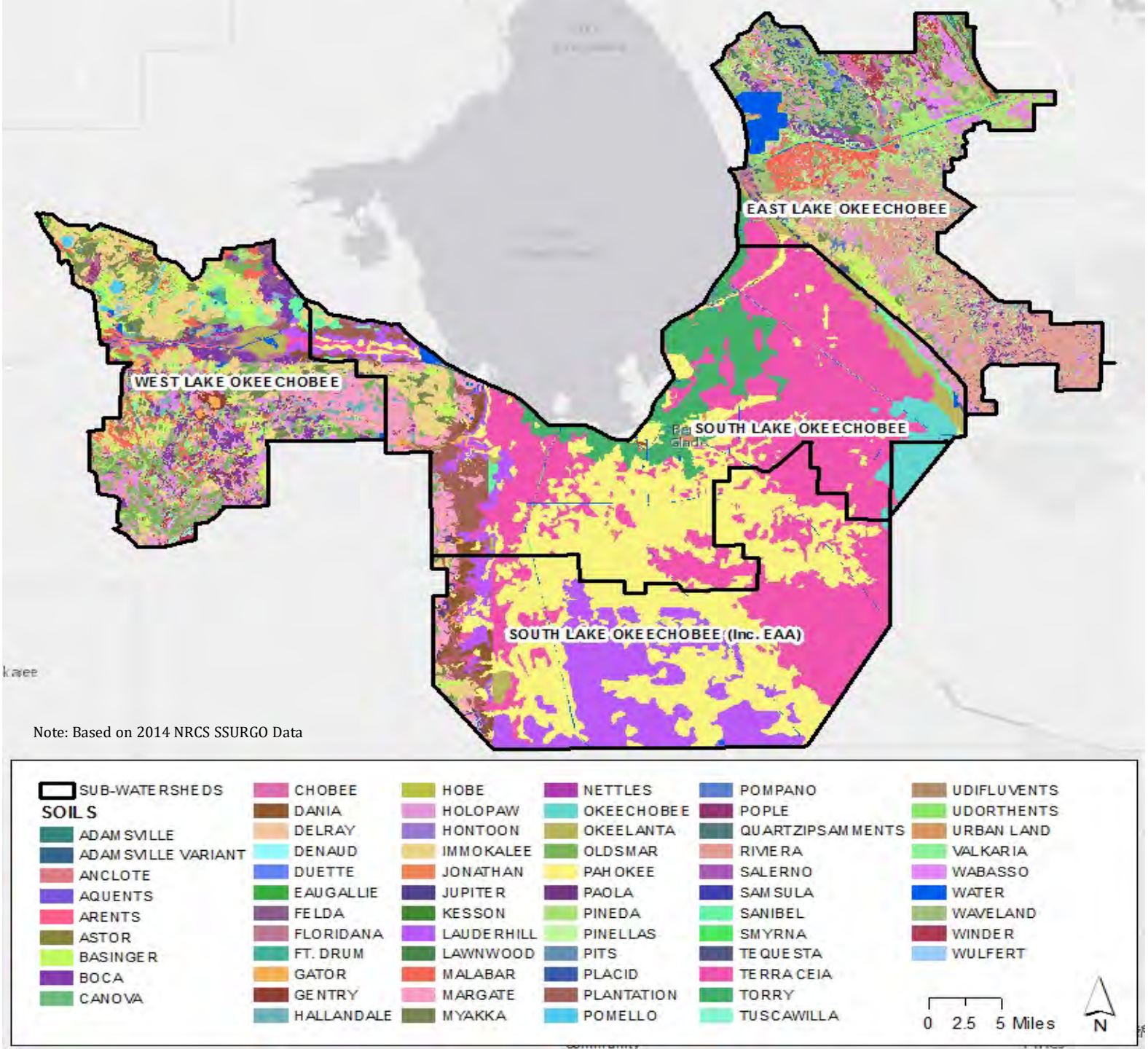
Presented by Del Bottcher

Soil and Water Engineering Technology, Inc.


Okeechobee BMAP Boundary
Northern Lake Okeechobee Sub-Watersheds
East Lake Okeechobee
West Lake Okeechobee
South Lake Okeechobee
Extended WAM Domain
STA 5/6
Rot. WMA
H.L. WMA
STAs 2-3/4

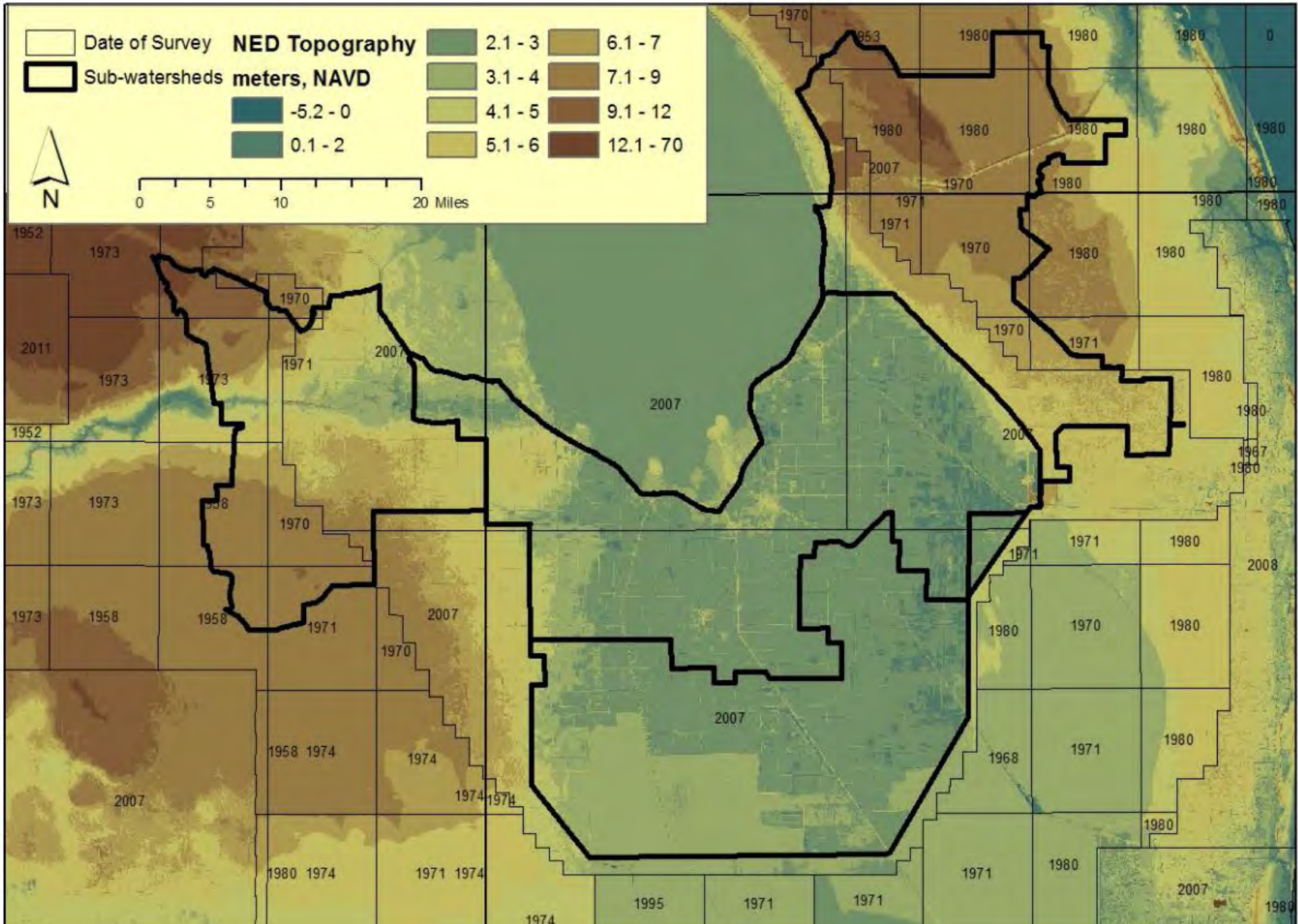

East Lake Okeechobee
West Lake Okeechobee
South Lake Okeechobee
S80
FPL-Pump
S308
C11
C10A
C5A
S77-Seepage
S47B
S77
G235
S47D
S78
S78-Bypass
S4
S4-Seepage
S169
S310
G236
S352-Seepage
S352
EastBeach_RS3
EB-Seepage
C10
C12A
C12
West Palm Beach Canal
WPS Water
298_M_1
S5A-E/W/S
G250
S5A
S2
S3
S3-Seepage
S2-Seepage
SFCD5E
SSDDMC
C4A
G135
G136
Miami Canal
North New River Canal
Hillsboroi Canal
S6
G328
G434
G373
G372
G200
STA 5/6
Rot. WMA
H.L. WMA
G370
G435
STAs 2-3/4
S8
S7
Legend
Hydroedge- Canal/Streams
Minor Flow Boundary Structure
Major Flow Boundary Structure
Minor Simulated Structure
Major Simulated Structure
Farm Level Pump/Culvert

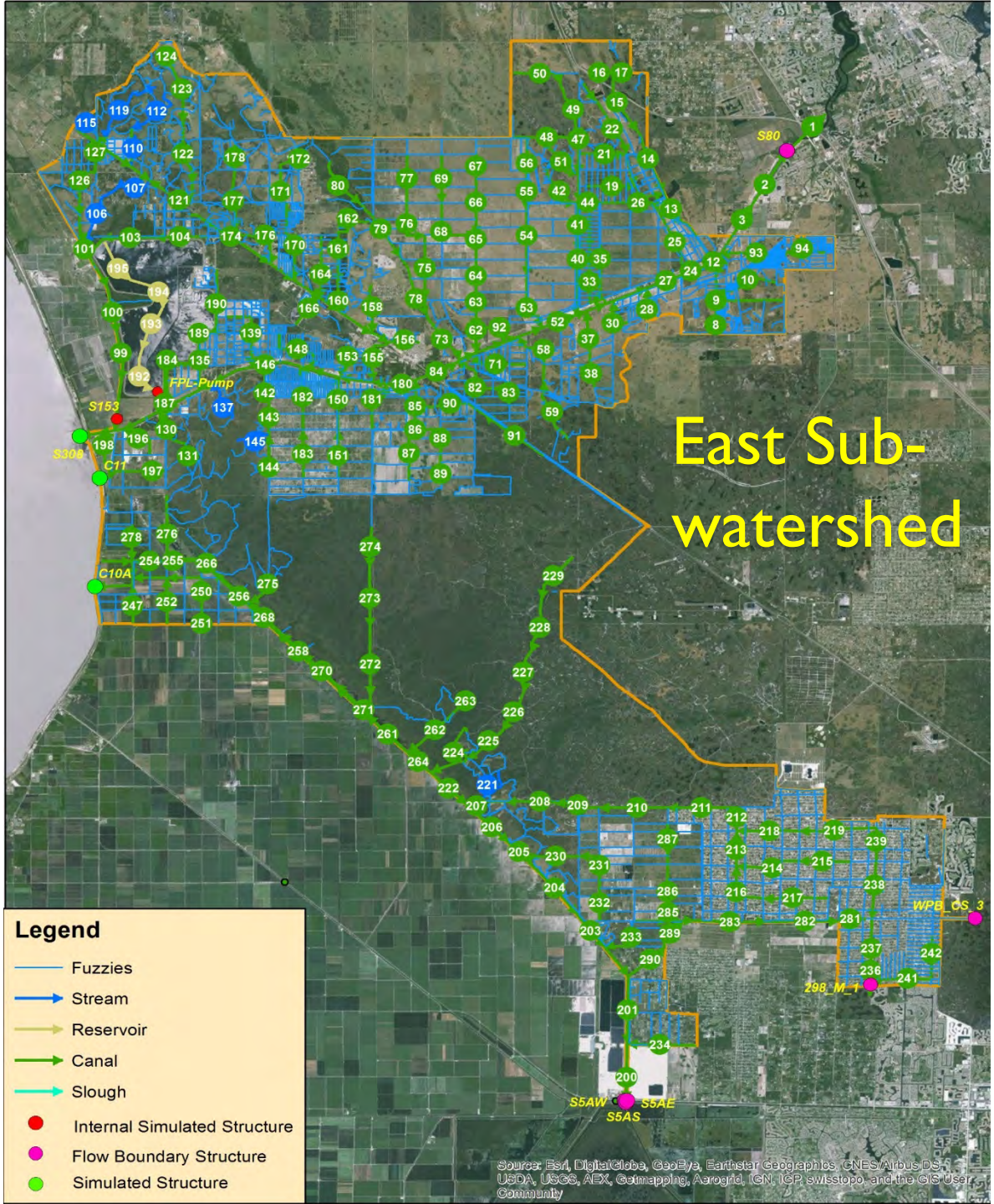

SUB-WATERSHEDS
WAM LAND USES
Animal Race Tracks
Aquaculture
Barren Land
Bay Swamps
Cattle Feeding Operation
Citrus Groves
Commercial and Services
Coniferous Plantations
Cypress
Dairies
Field Crops
Freshwater Marshes
Groves and Orchards
Hardwood Conifer Mixed
Hardwoods
High Density Residential
Horse Farms
Improved Pasture
Industrial
Low Density Residential
Managed Landscape
Medium Density Residential
Mining
Mixed Wetland Hardwoods
Multiple Dwelling Units
Open Water
Ornamental Nurseries
Poultry Feeding Operatio
Prisons
Row Crops
Scrub and Brushland
Sewage Treatment
Sod Farms
Solid Waste Disposal
Sugar Cane
Transportation Corridors
Tree Nurseries
Undeveloped Urban Land
Unimproved Pasture
Wetland Forested Mixed
Woodland Pasture
0
4
8 Miles
N
EAST LAKE OKEECHOBEE
WEST LAKE OKEECHOBEE
SOUTH LAKE OKEECHOBEE
SOUTH LAKE OKEECHOBEE (Inc. EAA)

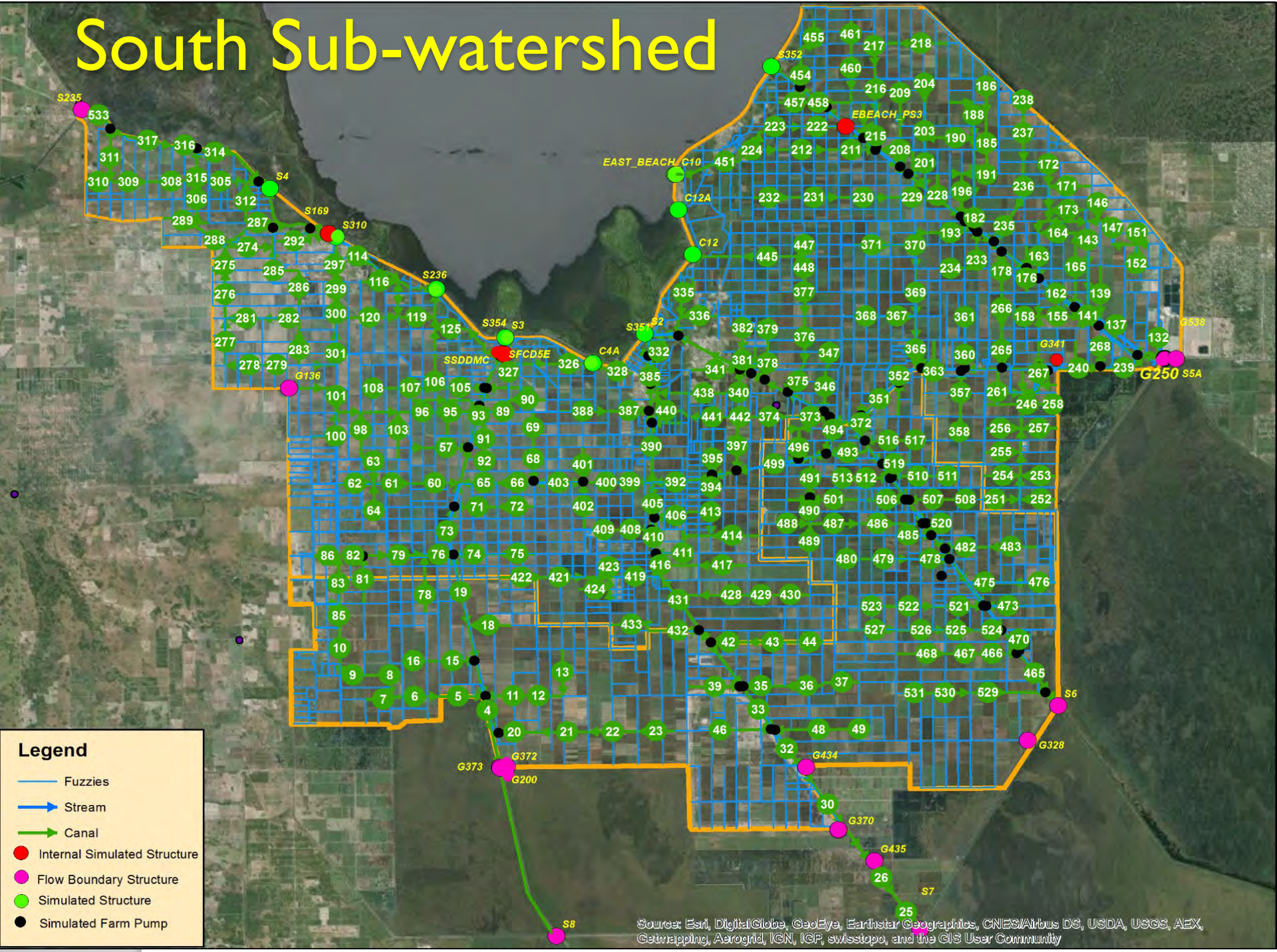


Note: Based on 2014 NRCS SSURGO Data

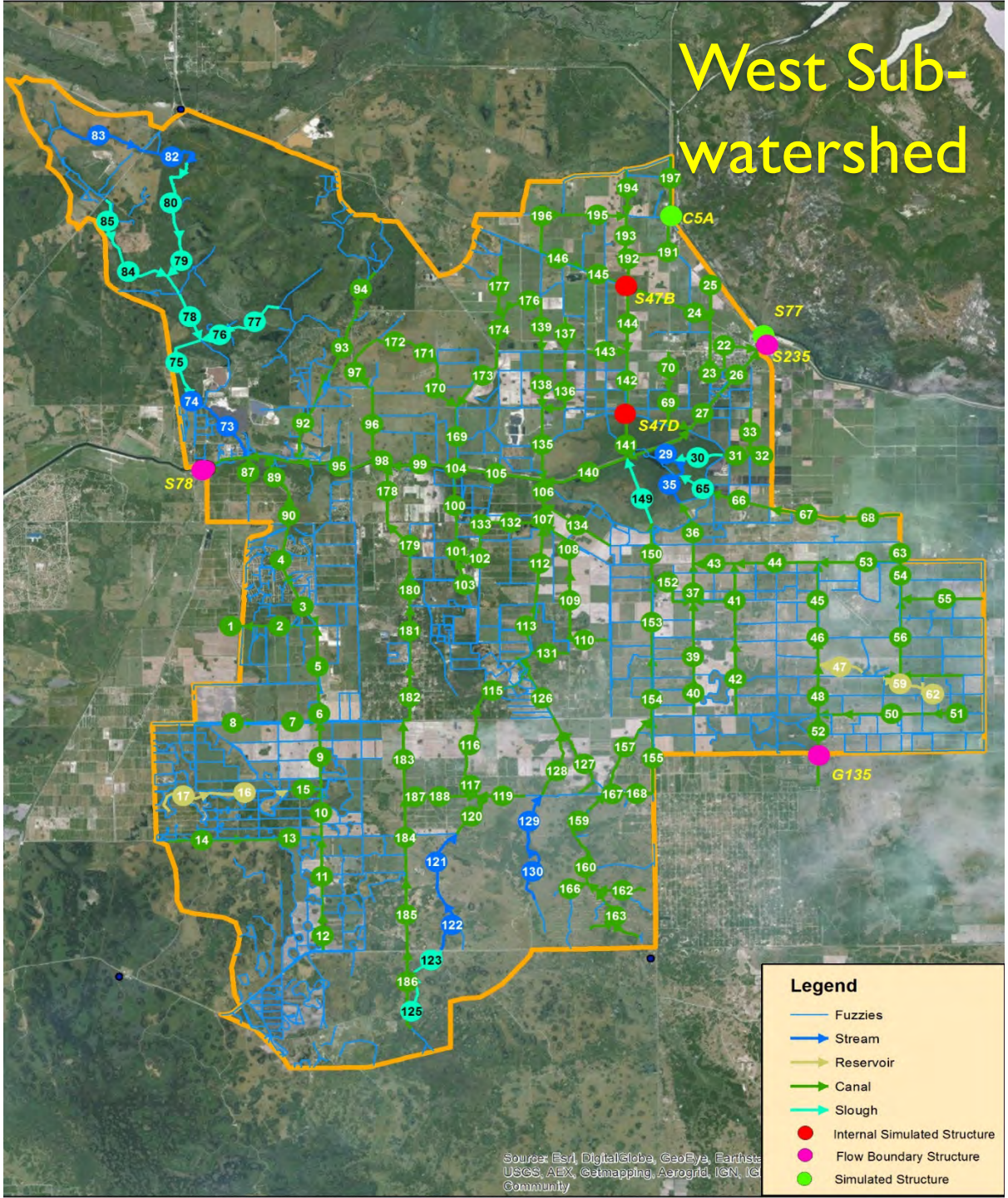
Topography

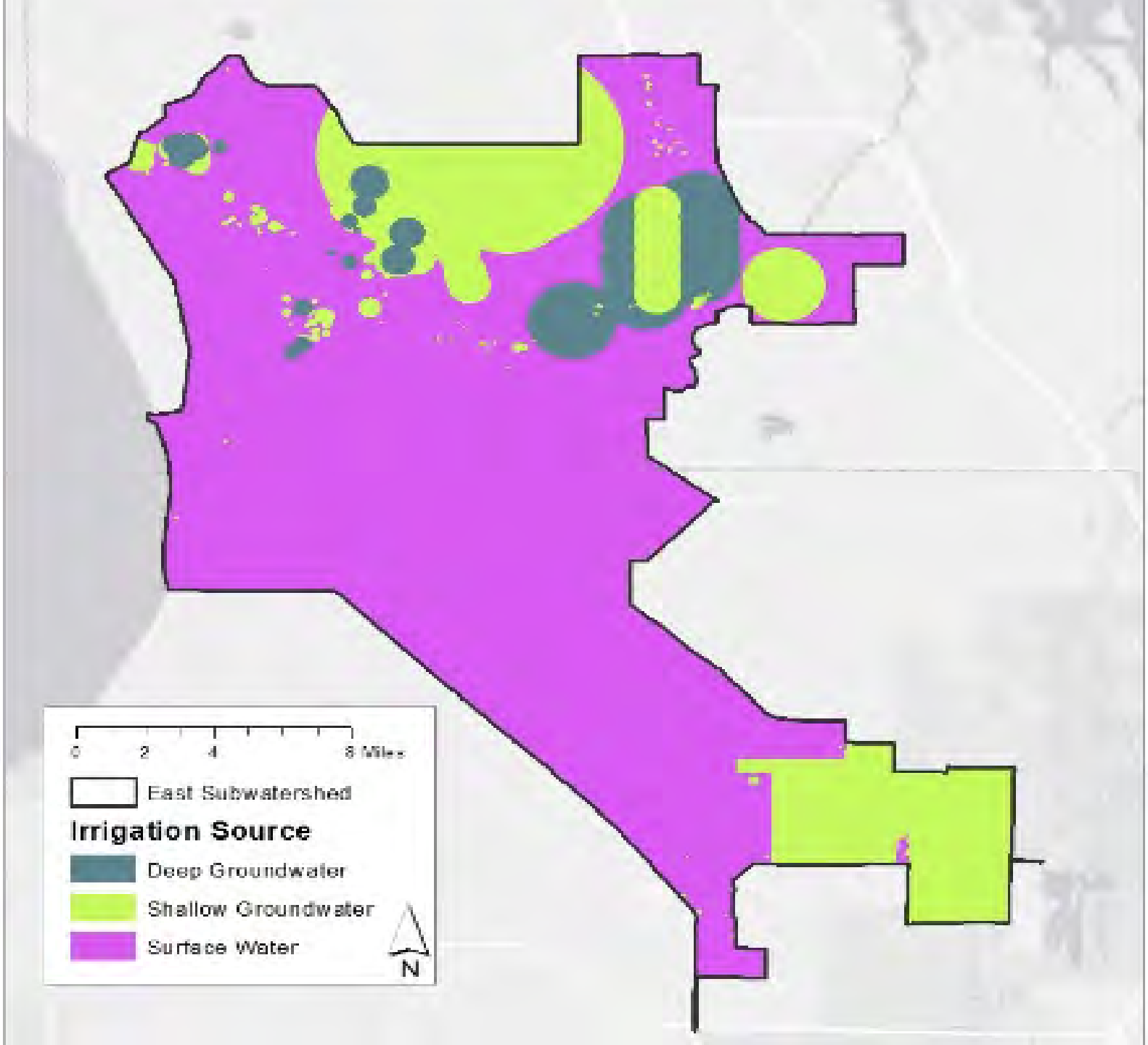

Date of Survey
Sub-watersheds
NED Topography
meters, NAVD
-5.2 - 0
0.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 7
7.1 - 9
9.1 - 12
12.1 - 70
N
0
5
10
20 Miles

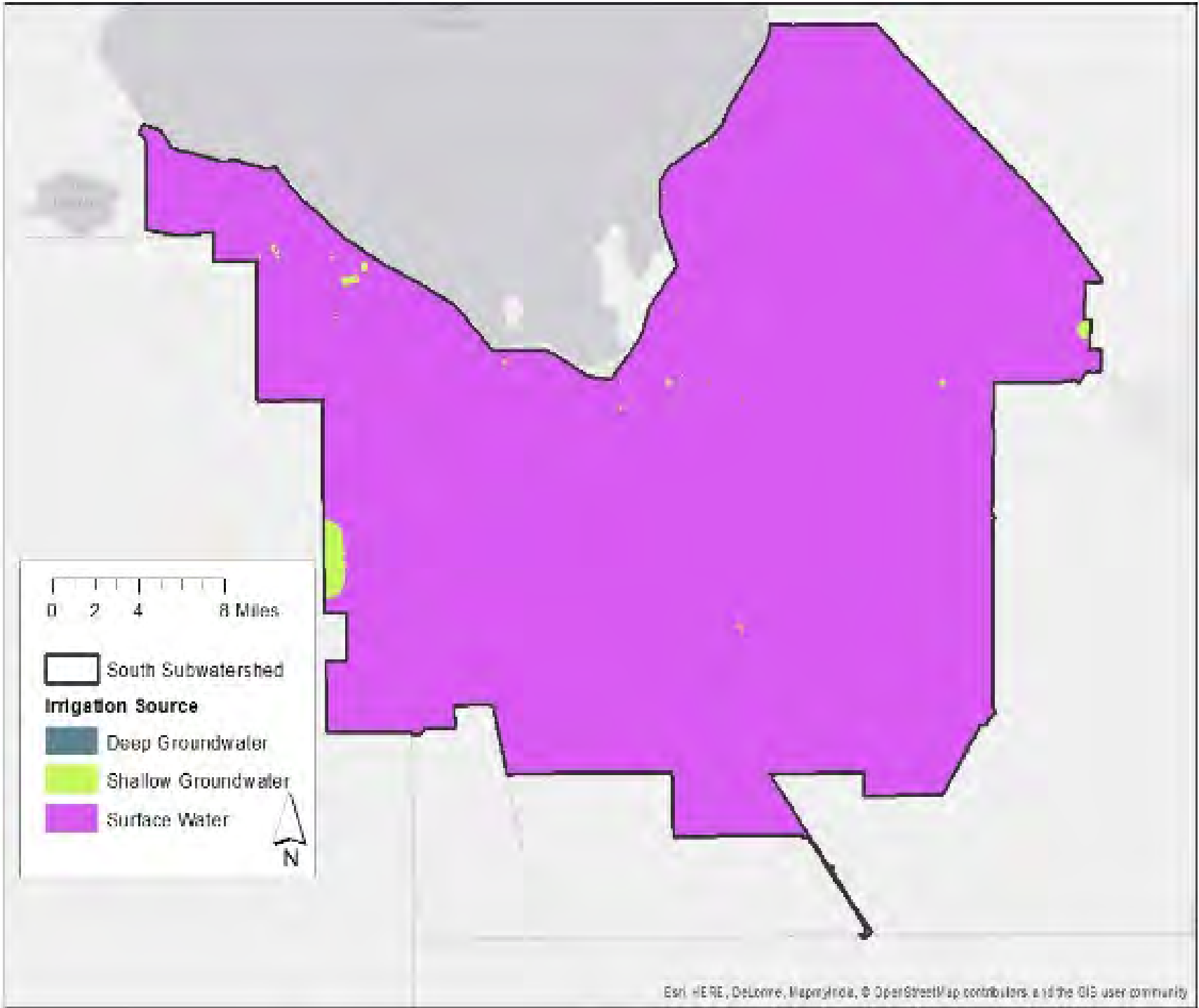

East Sub-watershed
Legend
Fuzzies
Stream
Reservoir
Canal
Slough
Internal Simulated Structure
Flow Boundary Structure
Simulated Structure
S80
FPL-Pump
S153
S308
C11
C10A
WPB_OS_3
298_M_1
S5AW
S5AE
S5AS
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

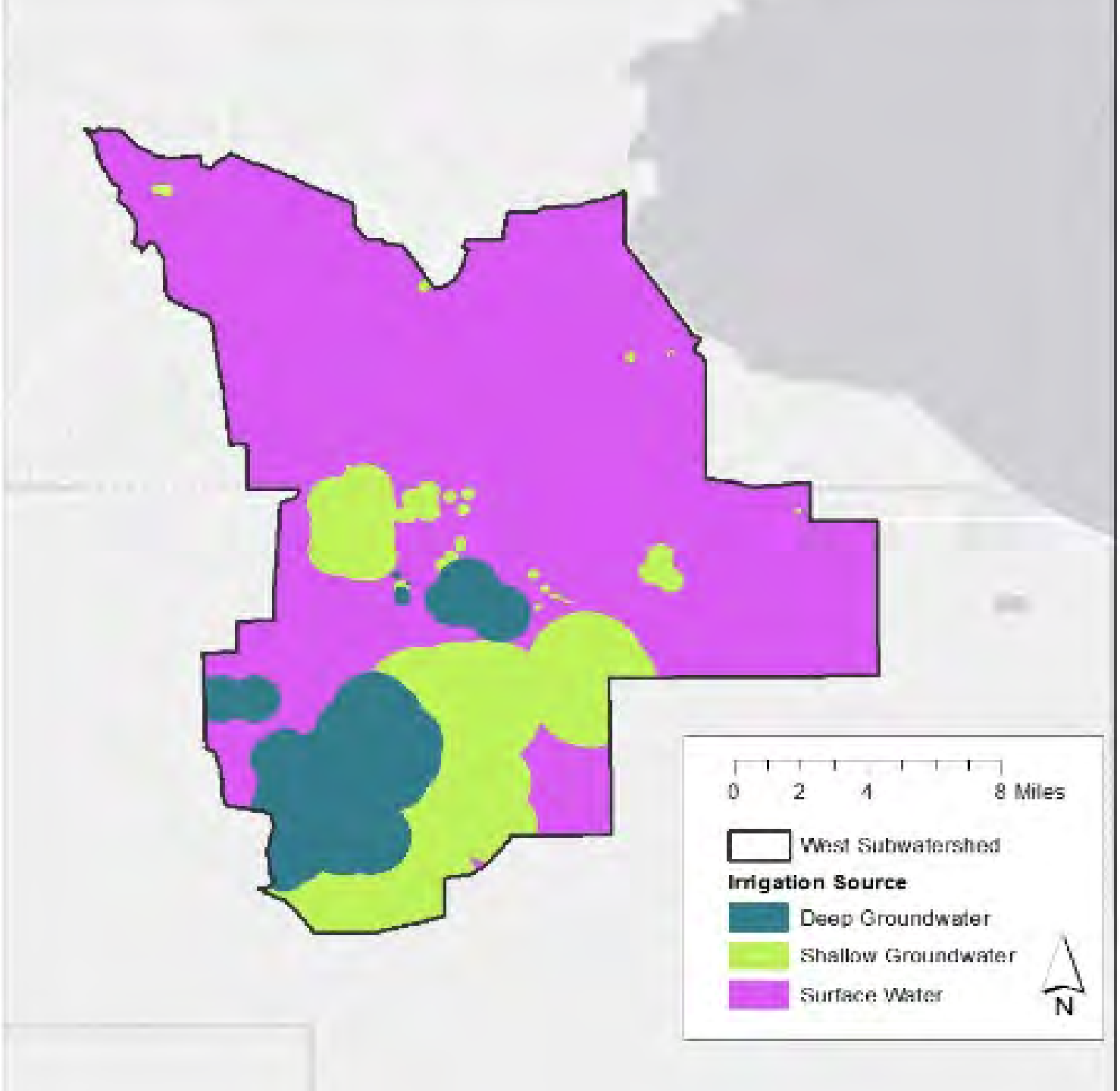

South Sub-watershed
S235
S4
S169
S310
S236
S354
S3
SFCD5E
SSDDMC
G136
S352
EBEACH_PS3
EAST_BEACH
C10
C12A
C12
S351
S2
C4A
G341
G538
G250
S5A
S6
G328
G434
G372
G373
G200
G370
G435
S7
S8
Legend
Fuzzies
Stream
Canal
Internal Simulated Structure
Flow Boundary Structure
Simulated Structure
Simulated Farm Pump
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

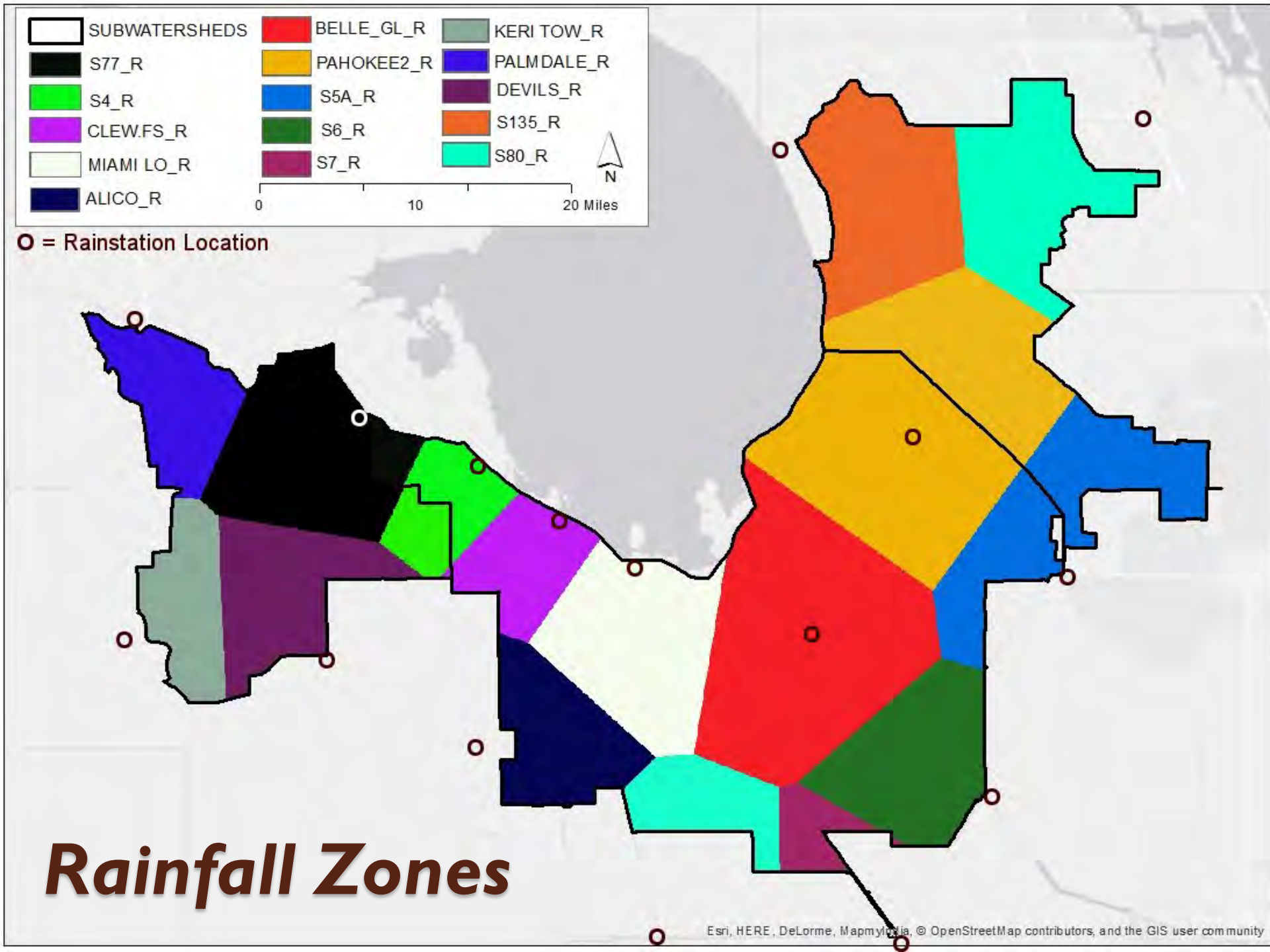
West Sub-watershed




0
2
4
8 Miles
East Subwatershed
Irrigation Source
Deep Groundwater
Shallow Groundwater
Surface Water
N


0 2 4 8 Miles
South Subwatershed
Irrigation Source
Deep Groundwater
Shallow Groundwater
Surface Water
N
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

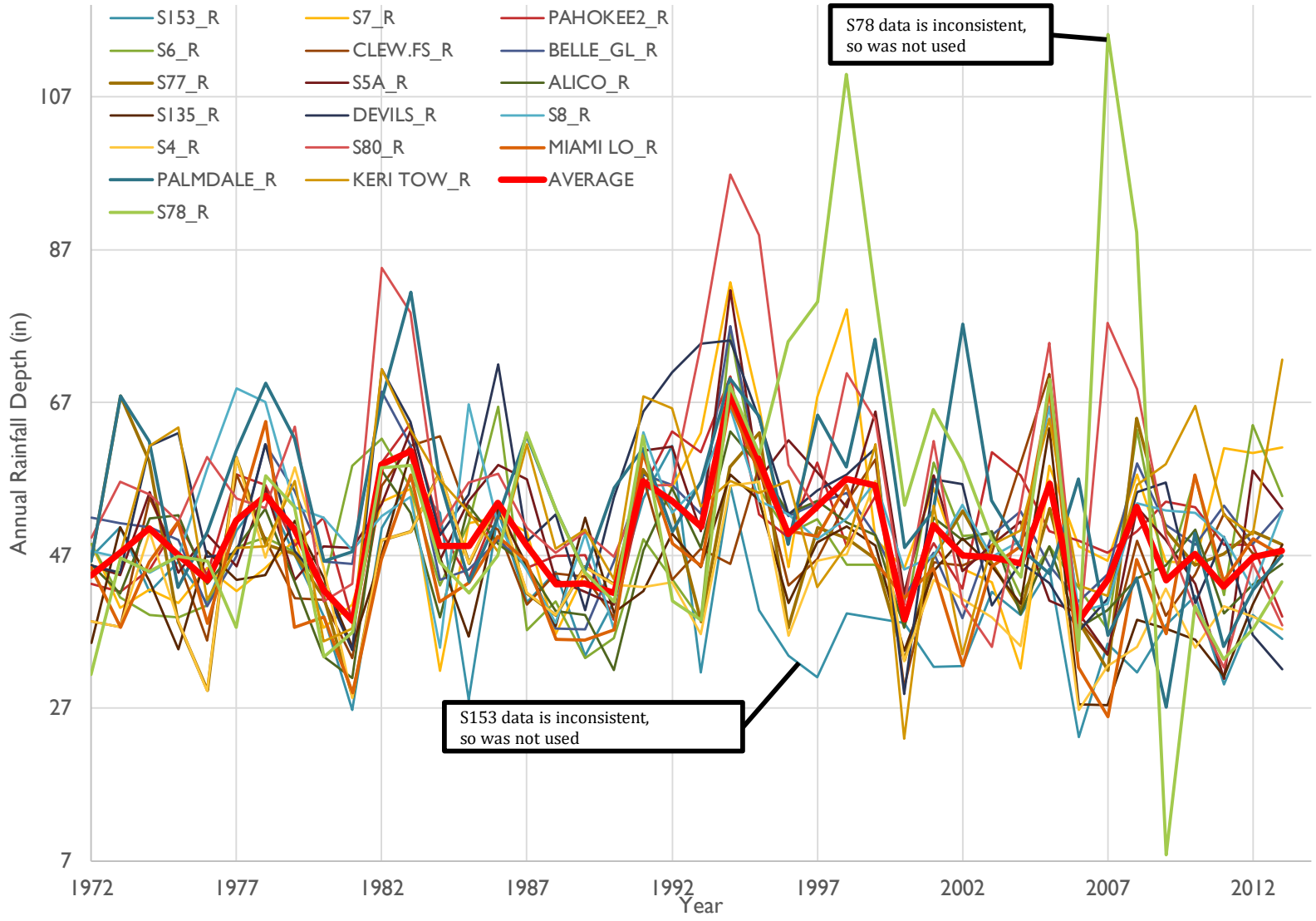

0 2 4 8 Miles
West Subwatershed
Irrigation Source
Deep Groundwater
Shallow Groundwater
Surface Water
N


SUBWATERSHEDS
S77_R
S4_R
CLEW.FS_R
MIAMI LO_R
ALICO_R
BELLE_GL_R
PAHOKEE2_R
S5A_R
S6_R
S7_R
KERI TOW_R
PALMDALE_R
DEVILS_R
S135_R
S80_R
N
0
10
20 Miles
O = Rainstation Location
Rainfall Zones
Esri, HERE, DeLorme, Mapmyindia, © OpenStreetMap contributors, and the GIS user community

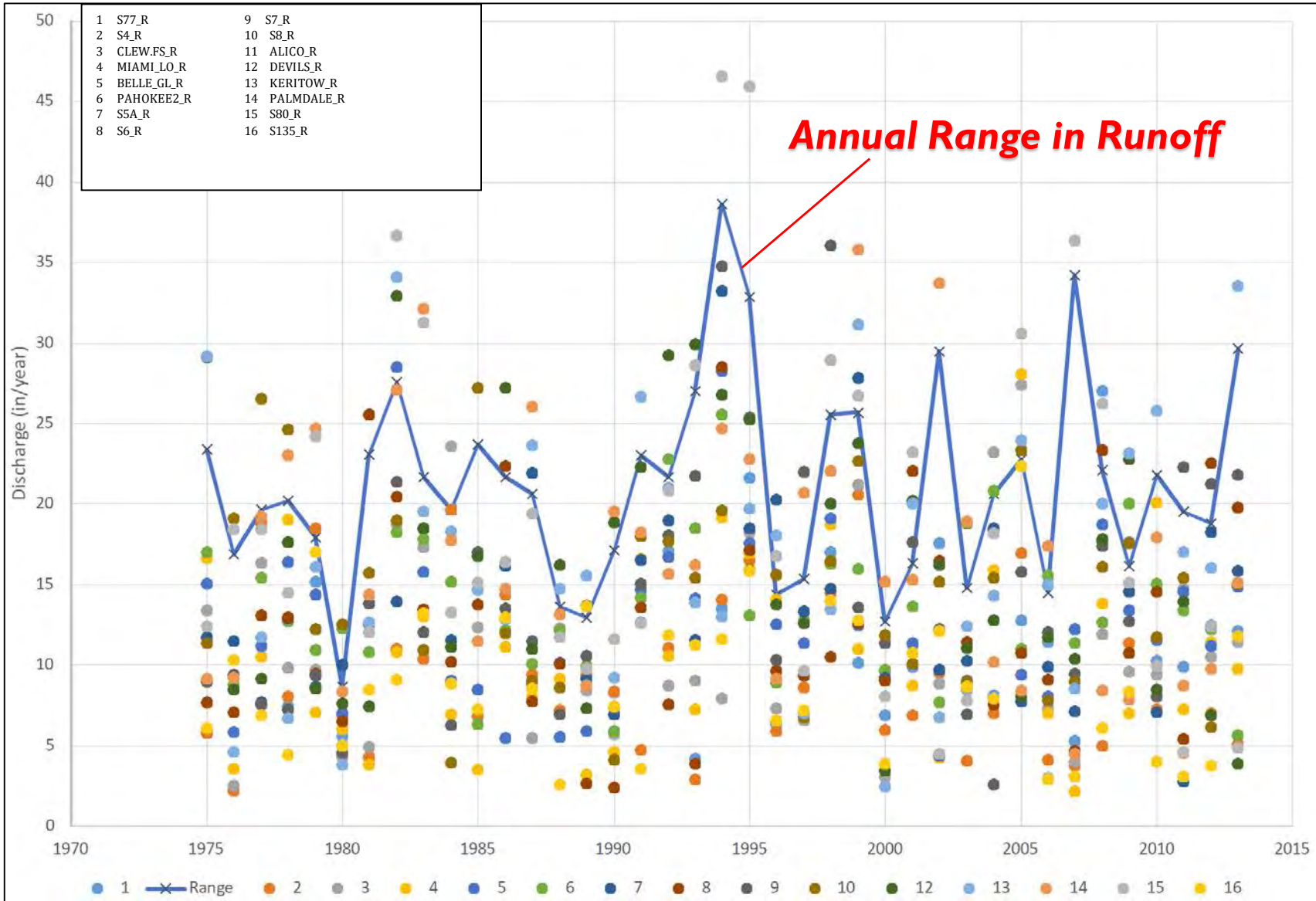
Accuracy of Input Data?

- ***Land Use and Soil Data***
  - Temporal Changes in land use
  - Knowing land practices?
  - Subsidence and soil management history impacts
- ***Weather Data***
  - Rainfall and ET variability
- ***Boundary Data***
  - Measurement issues, temporal changes, and recycling
- ***Water Quality Varies Across Lake Okeechobee***

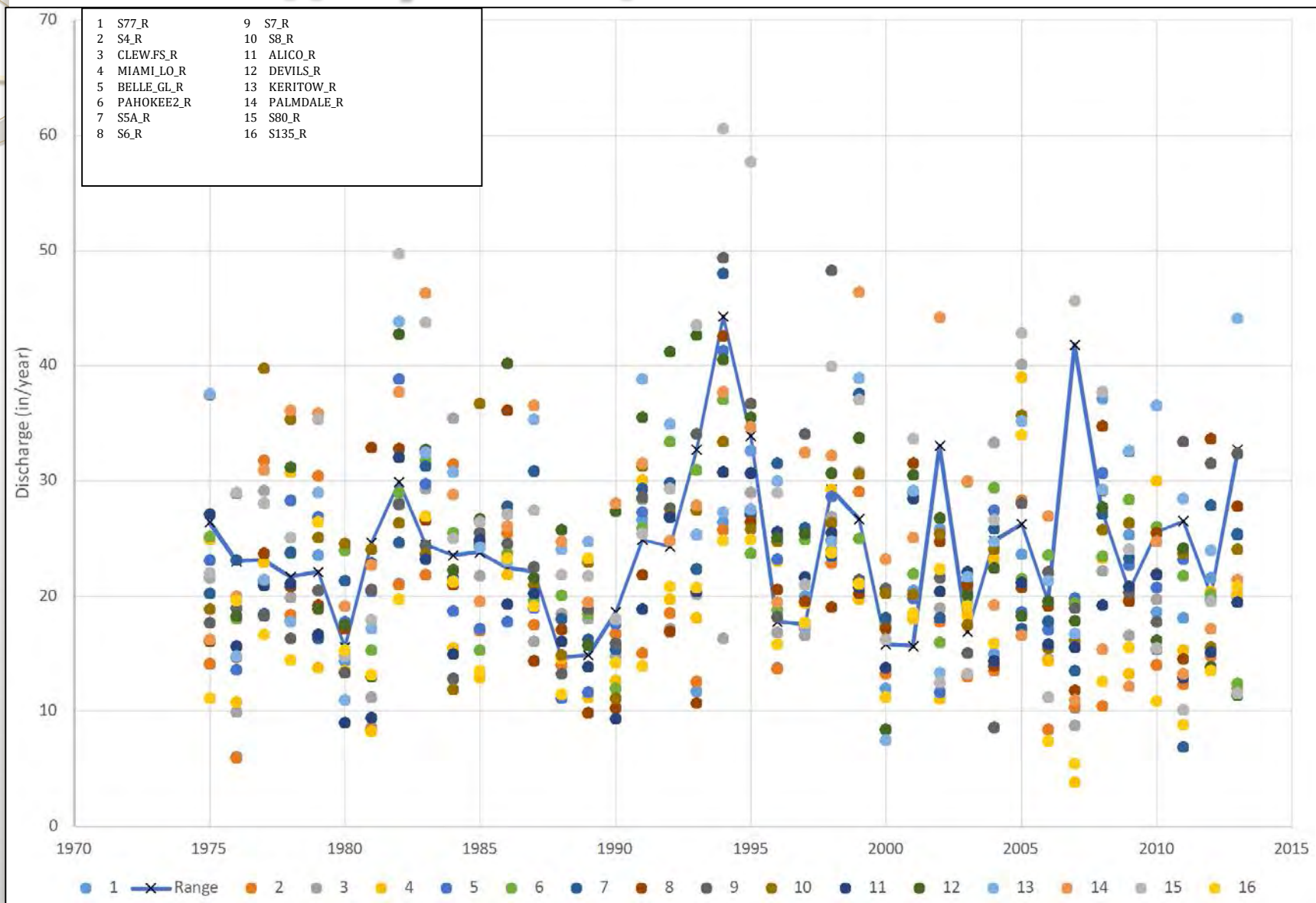
How Accurate is Rainfall Data?



Simulated Annual Residential Runoff by Rainfall Station



Simulated Annual Sugarcane Runoff by Rainfall Station

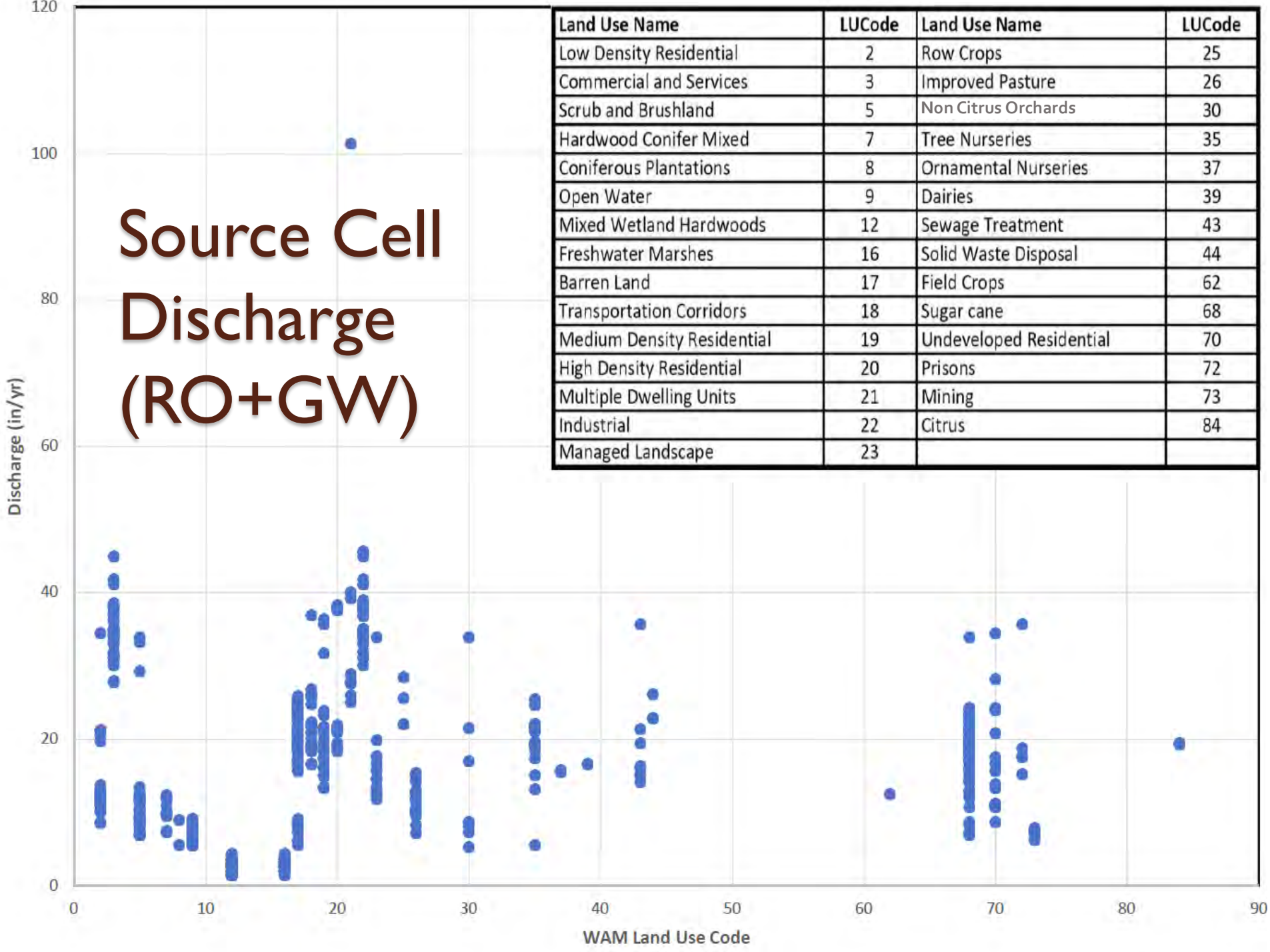


Calibration

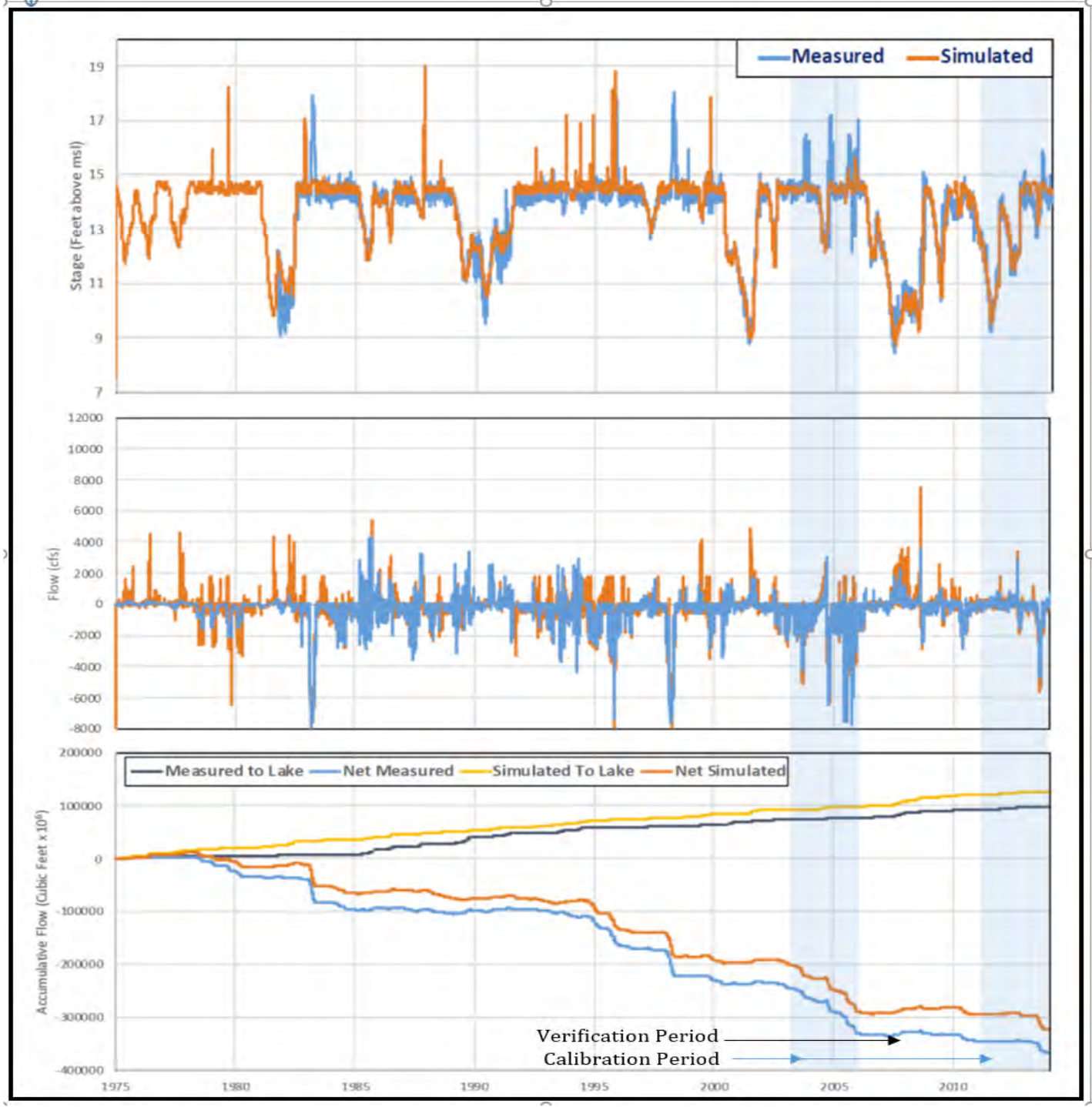
- Flow first, then nutrients
- Source cells first, then stream network

Source Cell Discharge (RO+GW)

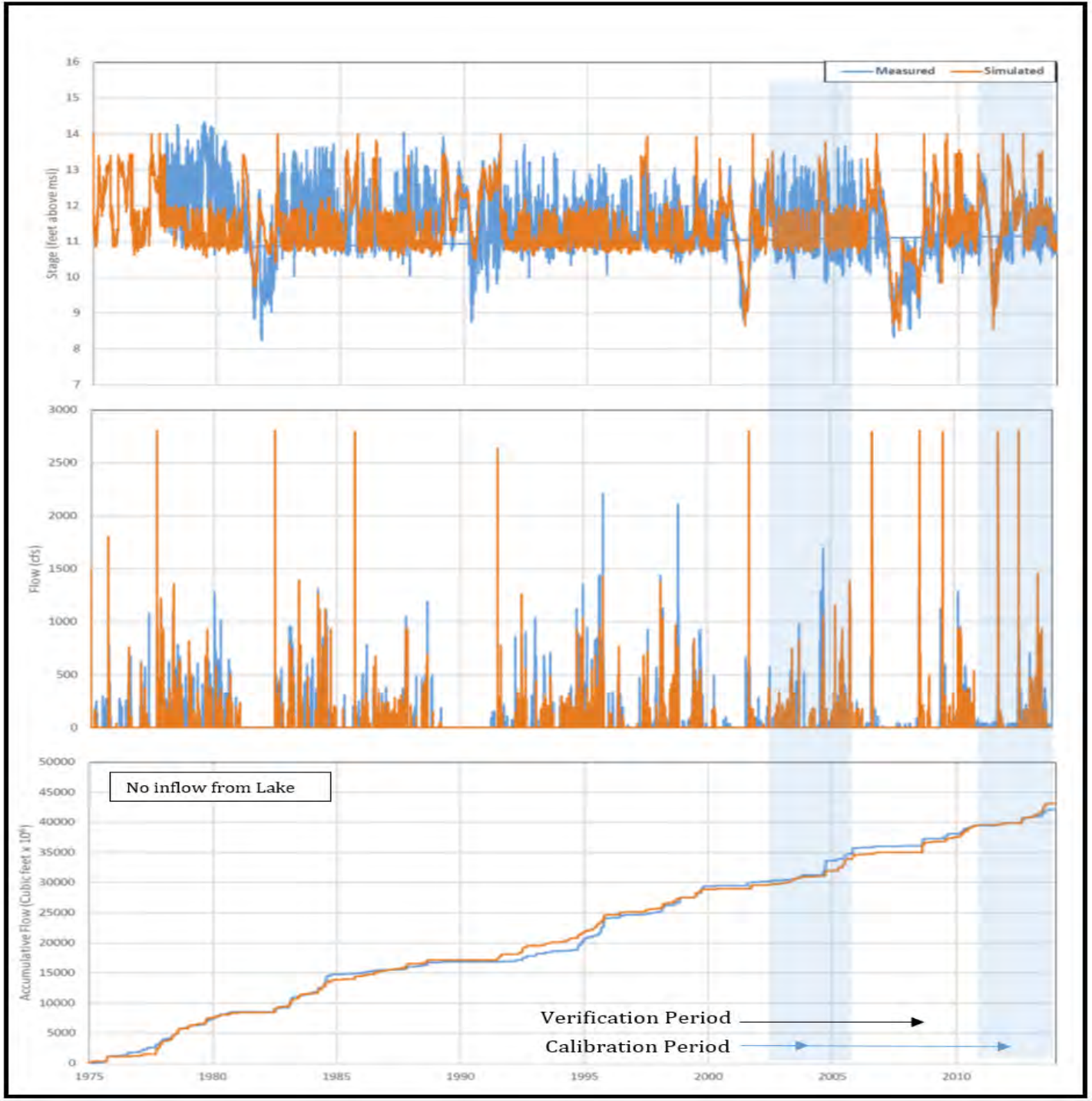
Land Use Name	LUCode	Land Use Name	LUCode
Low Density Residential	2	Row Crops	25
Commercial and Services	3	Improved Pasture	26
Scrub and Brushland	5	Non Citrus Orchards	30
Hardwood Conifer Mixed	7	Tree Nurseries	35
Coniferous Plantations	8	Ornamental Nurseries	37
Open Water	9	Dairies	39
Mixed Wetland Hardwoods	12	Sewage Treatment	43
Freshwater Marshes	16	Solid Waste Disposal	44
Barren Land	17	Field Crops	62
Transportation Corridors	18	Sugar cane	68
Medium Density Residential	19	Undeveloped Residential	70
High Density Residential	20	Prisons	72
Multiple Dwelling Units	21	Mining	73
Industrial	22	Citrus	84
Managed Landscape	23		



S-308


Measured
Simulated
Stage (Feet above msl)
19
17
15
13
11
9
7
Flow (cfs)
12000
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
Measured to Lake
Net Measured
Simulated To Lake
Net Simulated
Accumulative Flow (Cubic Feet x 10⁶)
200000
100000
0
-100000
-200000
-300000
-400000
Verification Period
Calibration Period
1975
1980
1985
1990
1995
2000
2005
2010

S-4

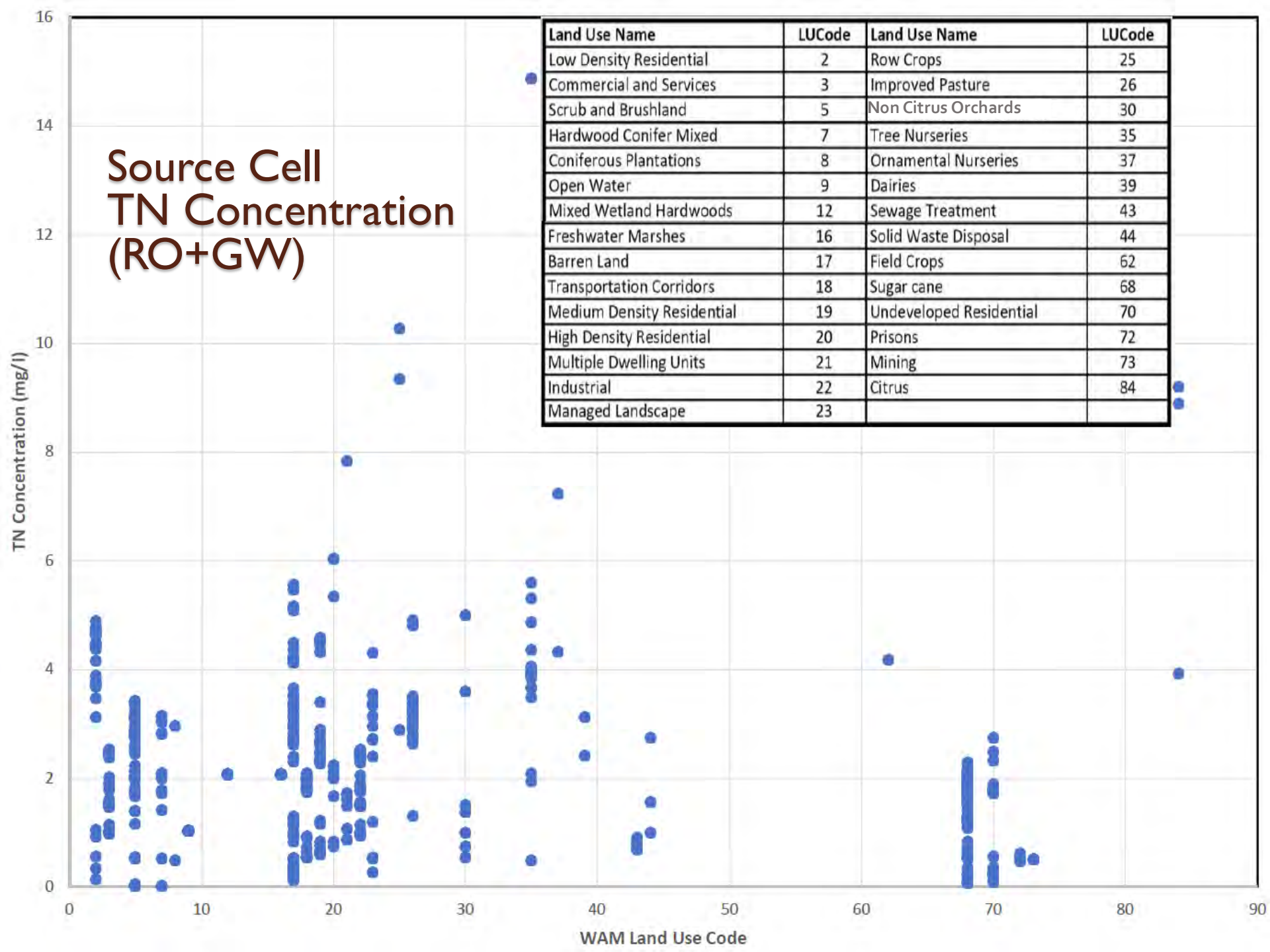

Measured
Simulated
Stage (feet above msl)
16
15
14
13
12
11
10
9
8
7
Flow (cfs)
3000
2500
2000
1500
1000
500
0
No inflow from Lake
Accumulative Flow (Cubic feet x 10⁶)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Verification Period
Calibration Period
1975
1980
1985
1990
1995
2000
2005
2010

Calibrated Flows

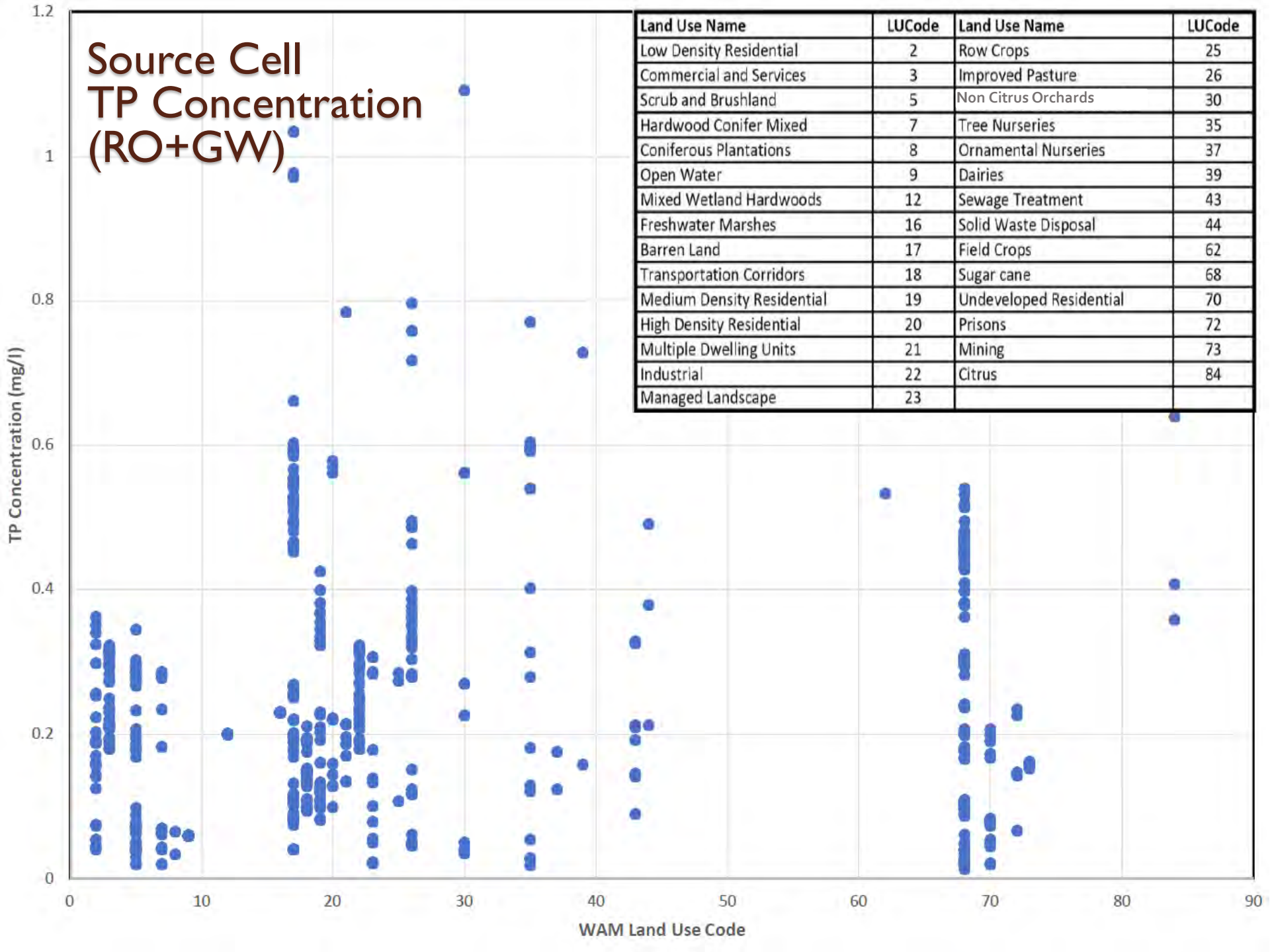
Structure Name	Accumulative Flow for Calibration Period* (Ac-ft/Yr)			
	Simulated	Measured	Diff.	RSME
S-308 on C44 Canal	-464,000	-422,000	8%	80,300
Culvert 10A on L8 Canal	-113,000	-102,000	10%	66,200
S-352 on WPB Canal	-113,000	-110,000	3%	41,300
S-2 on Hillsboro & NNR	-199, 000	-184,000	8%	118,000
S-3 on Miami Canal	-123,000	-128,000	-4%	79,500
S-4 Pump Station	31,700	30,700	3%	10,400
S-77 on C43 Canal	-1,170,000	-1,088,000	7%	88,200

Source Cell TN Concentration (RO+GW)

Land Use Name	LUCode	Land Use Name	LUCode
Low Density Residential	2	Row Crops	25
Commercial and Services	3	Improved Pasture	26
Scrub and Brushland	5	Non Citrus Orchards	30
Hardwood Conifer Mixed	7	Tree Nurseries	35
Coniferous Plantations	8	Ornamental Nurseries	37
Open Water	9	Dairies	39
Mixed Wetland Hardwoods	12	Sewage Treatment	43
Freshwater Marshes	16	Solid Waste Disposal	44
Barren Land	17	Field Crops	62
Transportation Corridors	18	Sugar cane	68
Medium Density Residential	19	Undeveloped Residential	70
High Density Residential	20	Prisons	72
Multiple Dwelling Units	21	Mining	73
Industrial	22	Citrus	84
Managed Landscape	23		

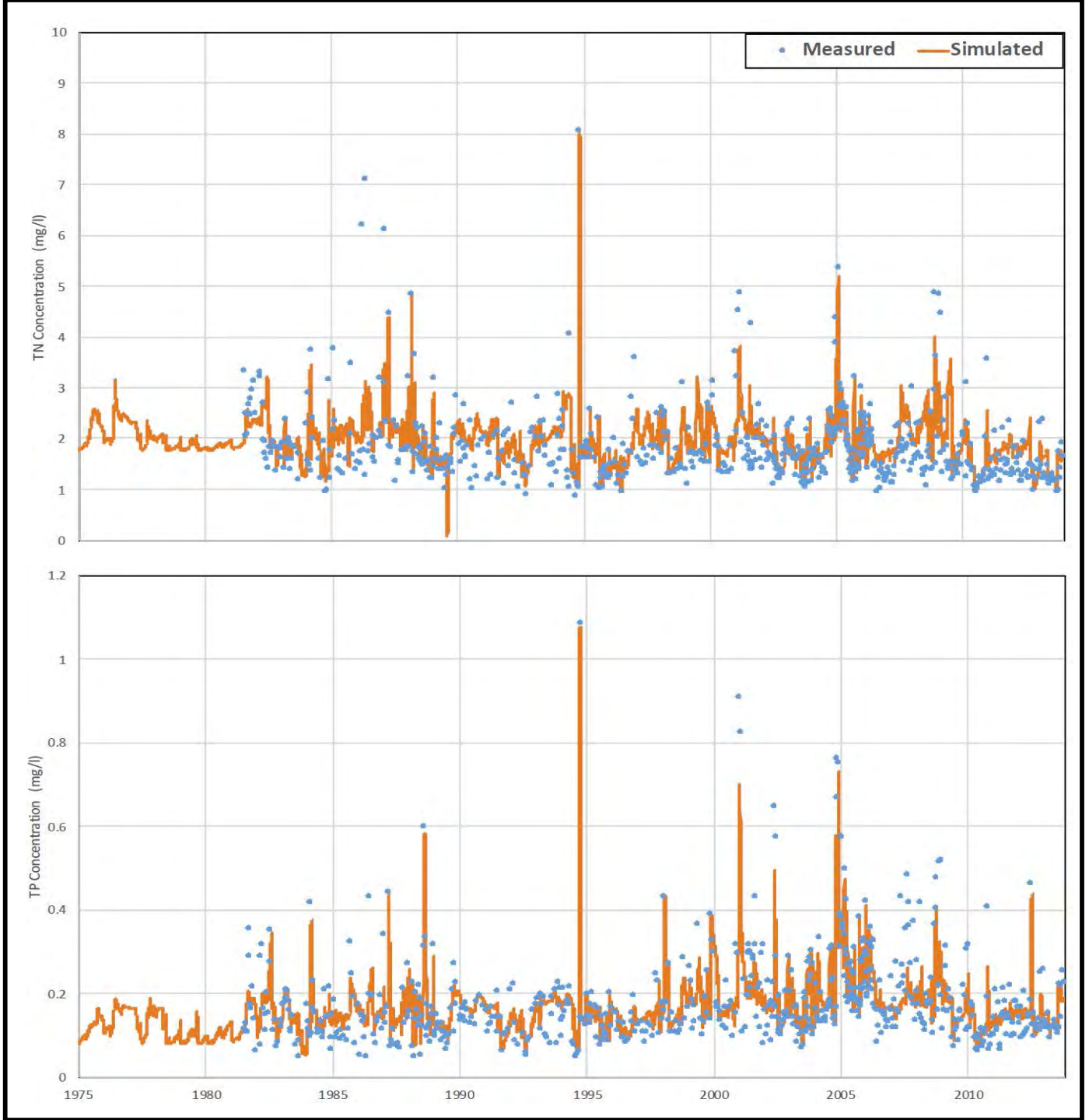


Source Cell TP Concentration (RO+GW)

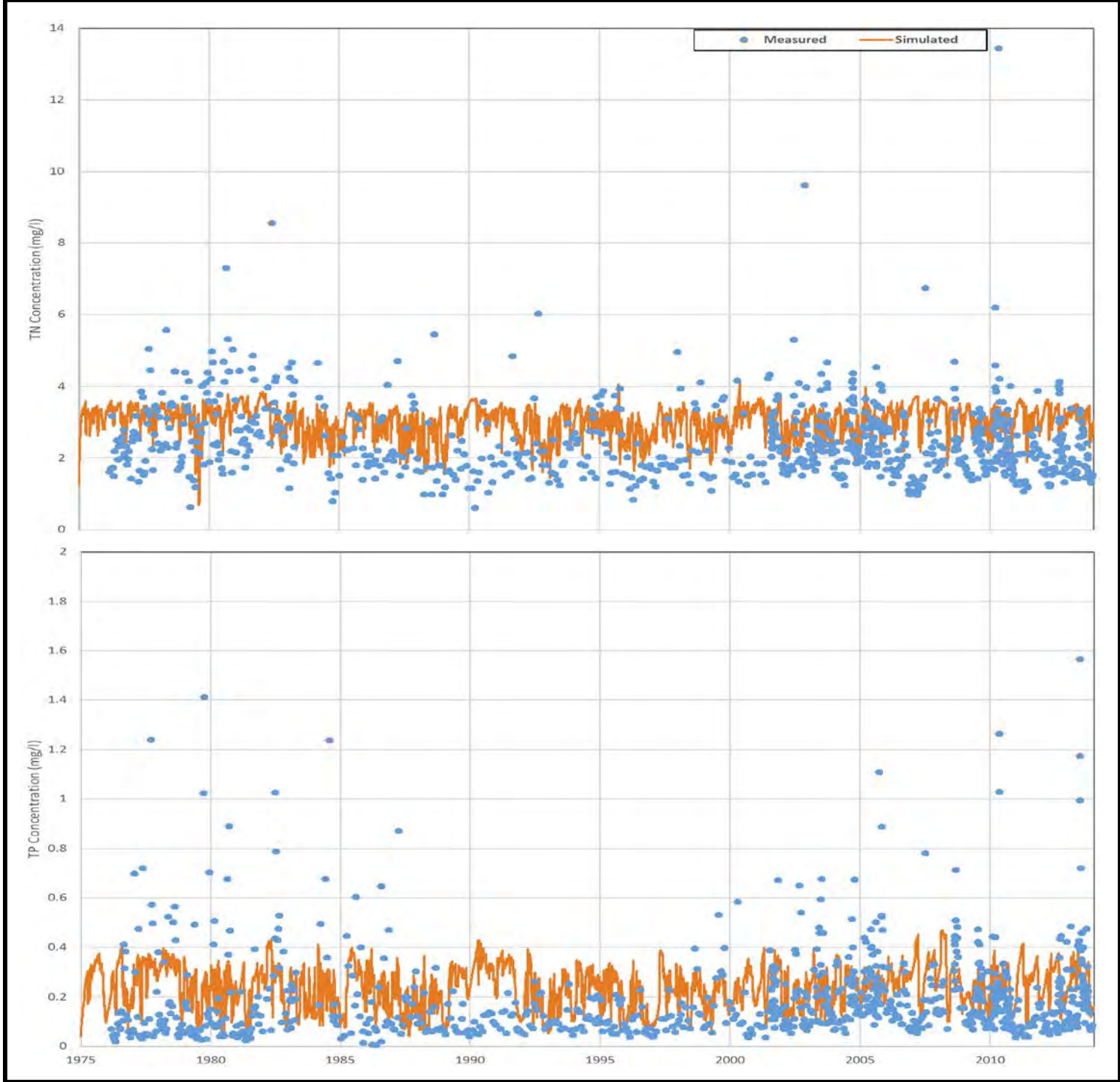


Land Use Name	LUCode	Land Use Name	LUCode
Low Density Residential	2	Row Crops	25
Commercial and Services	3	Improved Pasture	26
Scrub and Brushland	5	Non Citrus Orchards	30
Hardwood Conifer Mixed	7	Tree Nurseries	35
Coniferous Plantations	8	Ornamental Nurseries	37
Open Water	9	Dairies	39
Mixed Wetland Hardwoods	12	Sewage Treatment	43
Freshwater Marshes	16	Solid Waste Disposal	44
Barren Land	17	Field Crops	62
Transportation Corridors	18	Sugar cane	68
Medium Density Residential	19	Undeveloped Residential	70
High Density Residential	20	Prisons	72
Multiple Dwelling Units	21	Mining	73
Industrial	22	Citrus	84
Managed Landscape	23		

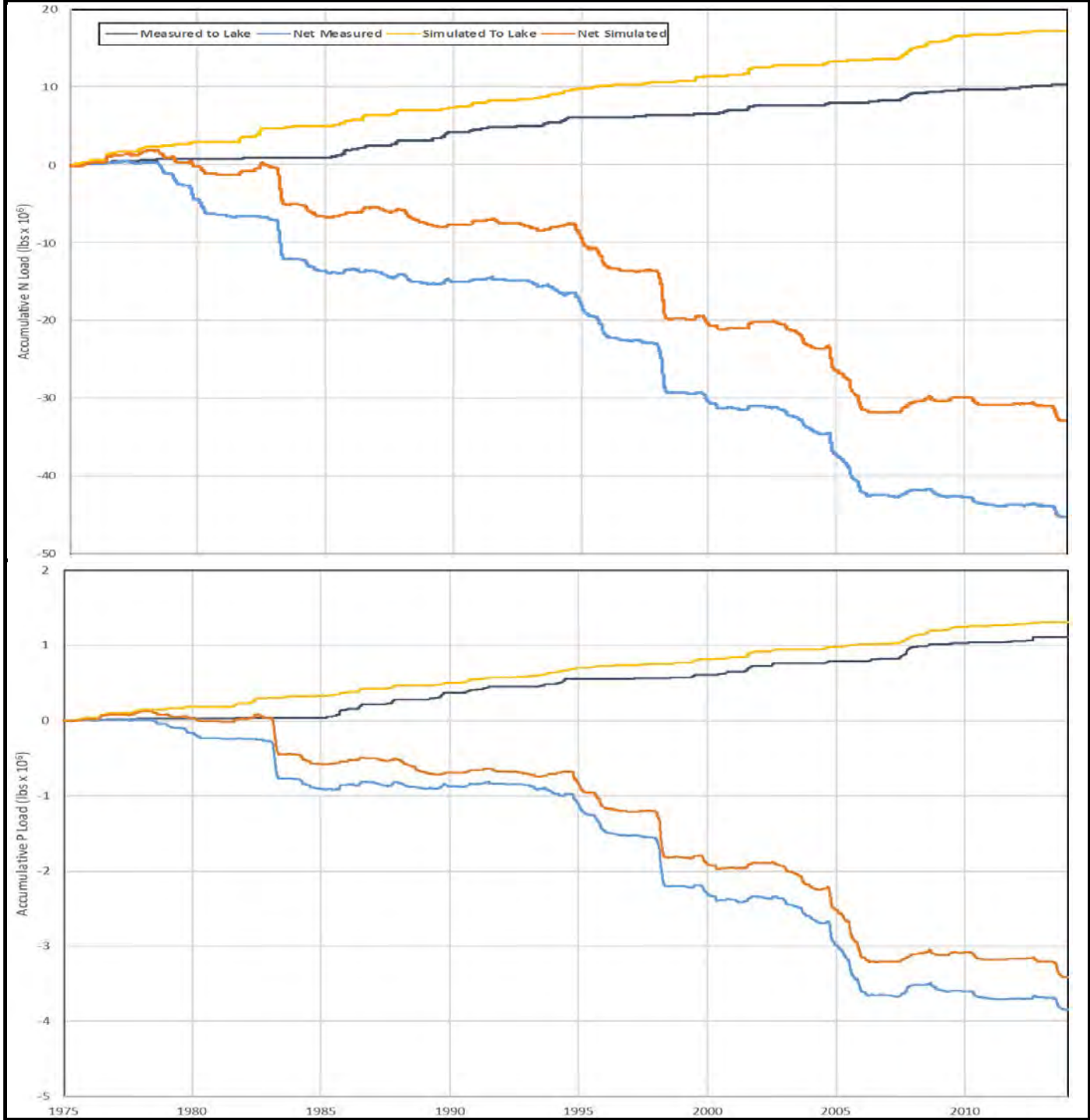
S-308


Measured
Simulated
TN Concentration (mg/l)
0
1
2
3
4
5
6
7
8
9
10
TP Concentration (mg/l)
0
0.2
0.4
0.6
0.8
1
1.2
1975
1980
1985
1990
1995
2000
2005
2010

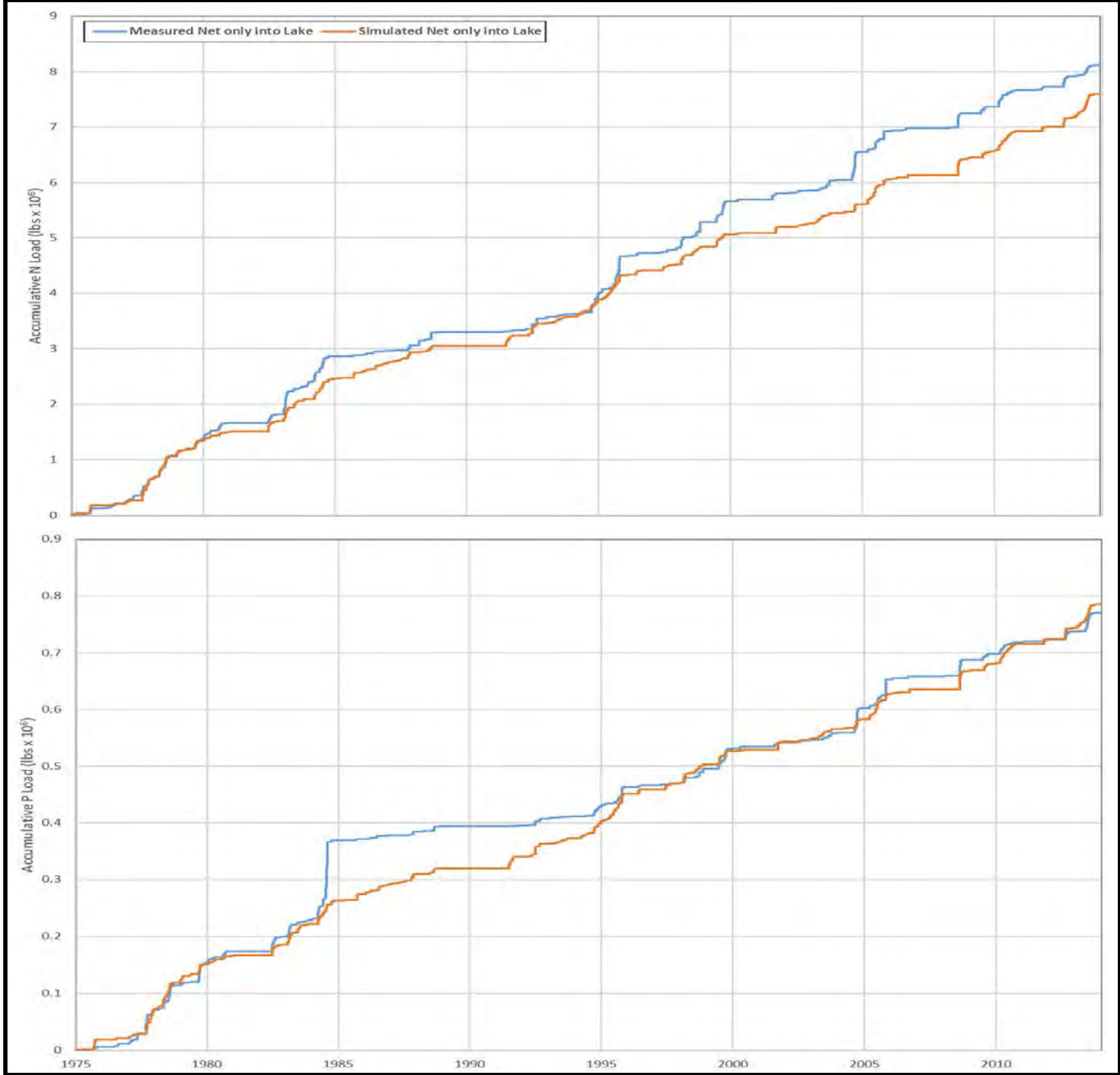
S-4


Measured
Simulated
TN Concentration (mg/l)
0
2
4
6
8
10
12
14
TP Concentration (mg/l)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1975
1980
1985
1990
1995
2000
2005
2010

S-308


Measured to Lake
Net Measured
Simulated To Lake
Net Simulated
Accumulative N Load (lbs x 10⁶)
20
10
0
-10
-20
-30
-40
-50
Accumulative P Load (lbs x 10⁶)
2
1
0
-1
-2
-3
-4
-5
1975
1980
1985
1990
1995
2000
2005
2010

S-4


Measured Net only into Lake
Simulated Net only into Lake
Accumulative N Load (lbs x 10⁶)
0
1
2
3
4
5
6
7
8
9
Accumulative P Load (lbs x 10⁶)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1975
1980
1985
1990
1995
2000
2005
2010

Calibrated TN and TP Loads

Structure Name	Total N for Calibration Period* (Tons/Yr)				Total P for Calibration Period* (Tons/Yr)			
	Simu-lated	Mea-sured	Diff.	RMSE	Simu-lated	Mea-sured	Diff.	RMSE
S-308 on C44 Canal	-1065	-998	5%	300	-120	-113	5%	19
Culvert 10A on L8	-308	-237	26%	229	-31	-35	-10%	13
S-352 on WPB Canal	-292	-275	6%	152	-36	--33	9%	11
S-2 on Hills & NNR	-505	-328	43%	650	-25	-22	12%	34
S-3 on Miami C	-310	-257	19%	544	-16	-15	4%	21
S-4 Pump Station	122	127	-5%	52	12	13	-7%	9
S-77 on C43 Canal	-2442	-2257	8%	249	-208	-191	8%	21

Goodness of Fit

$$E = 1 - \frac{\sum_{t=0}^{T} (Xo - X)^2}{\sum_{t=0}^{T} (Xo - \overline{Xo})^2}$$

Where,

E = Nash-Sutcliffe efficiency coefficient

Xo = Observed time series data (acre-ft or tons)

X = Modeled time series data (acre-ft or tons)

T = time period evaluated (years)

t = time step for summation (days, months, or years)

Calibration, Verification, and Nash-Sutcliffe Goodness of Fit Results for S-4

Calibration Period									
	Simulated			Measured			Difference		
	Flow	TN Loads	TP Loads	Flow	TN Loads	TP Loads	Flow	TN Loads	TP Loads
Six Years 2003-2005 & 2011-2013	(Ac-ft/Yr)	(Tons/Yr)	(Tons/Yr)	(Ac-ft/Yr)	(Tons/Yr)	(Tons/Yr)			
	31765	122	12	30728	127	13	3%	-5%	-7%
Verification Periods									
2006-2010	22694	87	9	17068	73	7	28%	18%	30%
1998-2013	25017	96	10	24430	103	9	2%	-7%	4%
Nash-Sutcliffe Efficiency "E" Coefficients									
	Annual Calculations			Monthly Calculations			Daily Calculations		
	Flow	TN Loads	TP Loads	Flow	TN Loads	TP Loads	Flow	TN Loads	TP Loads
2006-2010	0.59	0.90	0.62	0.85	0.91	0.93	-0.64	0.52	-87.80
1975-2013	0.74	0.66	0.49	0.57	0.55	0.41	-0.02	0.08	-0.04
1998-2013	0.54	0.42	0.65	0.57	0.54	0.59	-0.04	0.11	-0.27

Simulated and Measured Flows and TN and TP Loads

Structure ID	Sub-watershed	Into Lake Okeechobee						Out of Lake Okeechobee					
		Simulated			Measured[1,2]			Simulated			Measured[1,2]		
		Flow (ac-ft/yr)	TN Load (tons/yr)	TP Load (tons/yr)	Flow (ac-ft/yr)	TN Load (tons/yr)	TP Load (tons/yr)	Flow (ac-ft/yr)	TN Load (tons/yr)	TP Load (tons/yr)	Flow (ac-ft/yr)	TN Load (tons/yr)	TP Load (tons/yr)
S308	East	68332	210	17	52653	123	17	-328897	-809	-86	-325906	-814	-88
C11	East	1279	3.4	0.3	-	-	-	-441	-1.2	-0.1	-	-	-
C10A	East	67202	147	14	63082	184	8	-99416	-274	-26	-94017	-249	-26
Subtotal	**East**	**136813**	**360**	**31**	**115735**	**307**	**26**	**-428754**	**-1084**	**-112**	**-419923**	**-1062**	**-114**
S352	South	61	0.3	0.02	97	1.1	0.05	-112720	-314	-40	-115587	-302	-37
C10	South	1810	7	0.6	-	-	-	-933	-4	-0.4	-	-	-
C12A	South	0	0	0	-	-	-	-5550	-59	-1	-	-	-
S2	South	70602	703	29	29604	201	7	-240776	-1121	-51	-182427	-511	-28
C4A	South	2567	17	1	2533	-	-	-561	-3	-0.1	-	-	-
S3	South	37539	275	5	12766	78	2	-141207	-542	-19	-124801	-323	-15
G236	South	6427	49	0.5	9359	54	1.4	-1302	-5	-0.1	-	-	-
S310 Lock	South	14333	57	5	-	-	-	-23607	-63	-4	-	-	-
S4	South	25017	96	10	24430	103	9	0	0	0	0	0	0
Subtotal	**South**	**158355**	**1203**	**50**	**78788**	**437**	**20**	**-526657**	**-2111**	**-115**	**-422815**	**-1136**	**-80**
S77	West	25423	61	4	31250	81	7	-744504	-1663	-124	-725585	-1609	-117
C5A	West	1029	2	0	-	-	-	-25106	-55	-4	-	-	-
Subtotal	**West**	**26451**	**63**	**4**	**31250**	**81**	**7**	**-769611**	**-1719**	**-128**	**-725585**	**-1609**	**-117**
Total	**All Three**	**321620**	**1627**	**86**	**225774**	**825**	**52**	**-1725022**	**-4914**	**-355**	**-1568323**	**-3807**	**-311**

[1] Hyphens indicate measured data inadequate or not available.

[2] Red numbers indicated that not all structure are contributing to totals, therefore these values will under estimate actual flows and loads.

Future Scenario Runs

- Purpose of Scenario Runs
- Looking for input for possible future scenarios to run!
- Possible options beyond Baseline Run
  - Additional TMDL projects within BMAP Boundary (West Lake Okeechobee)
  - All/some CERP projects implemented
  - Land use changes
  - Advanced BMPs