SOUTHWEST MICHIGAN FARMERS FOR RESPONSIBLE WATER USE

CASS COUNTY PILOT PROJECT SUMMARY

THE CONCLUSIONS AND STATEMENTS CONTAINED HEREIN REPRESENT A CONSENSUS OF THE STEERING COMMITTEE AND THE TECHNICAL ADVISORY COMMITTEE MEMBERS BUT DO NOT REFLECT THE OPINION OF EVERY COMMITTEE MEMBER OR GROUP.

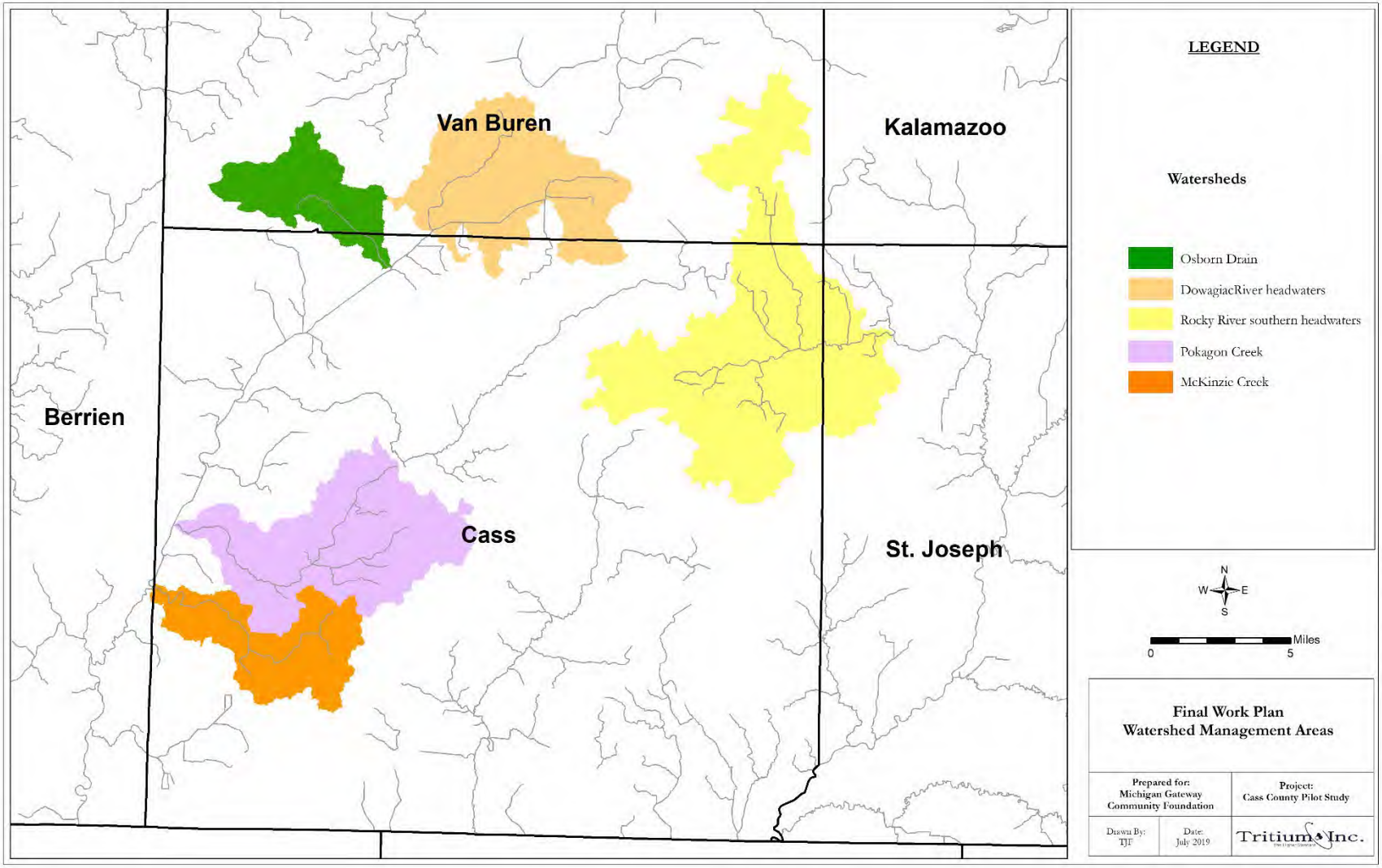
August 6, 2020

Tritium Inc.

Todd Feenstra

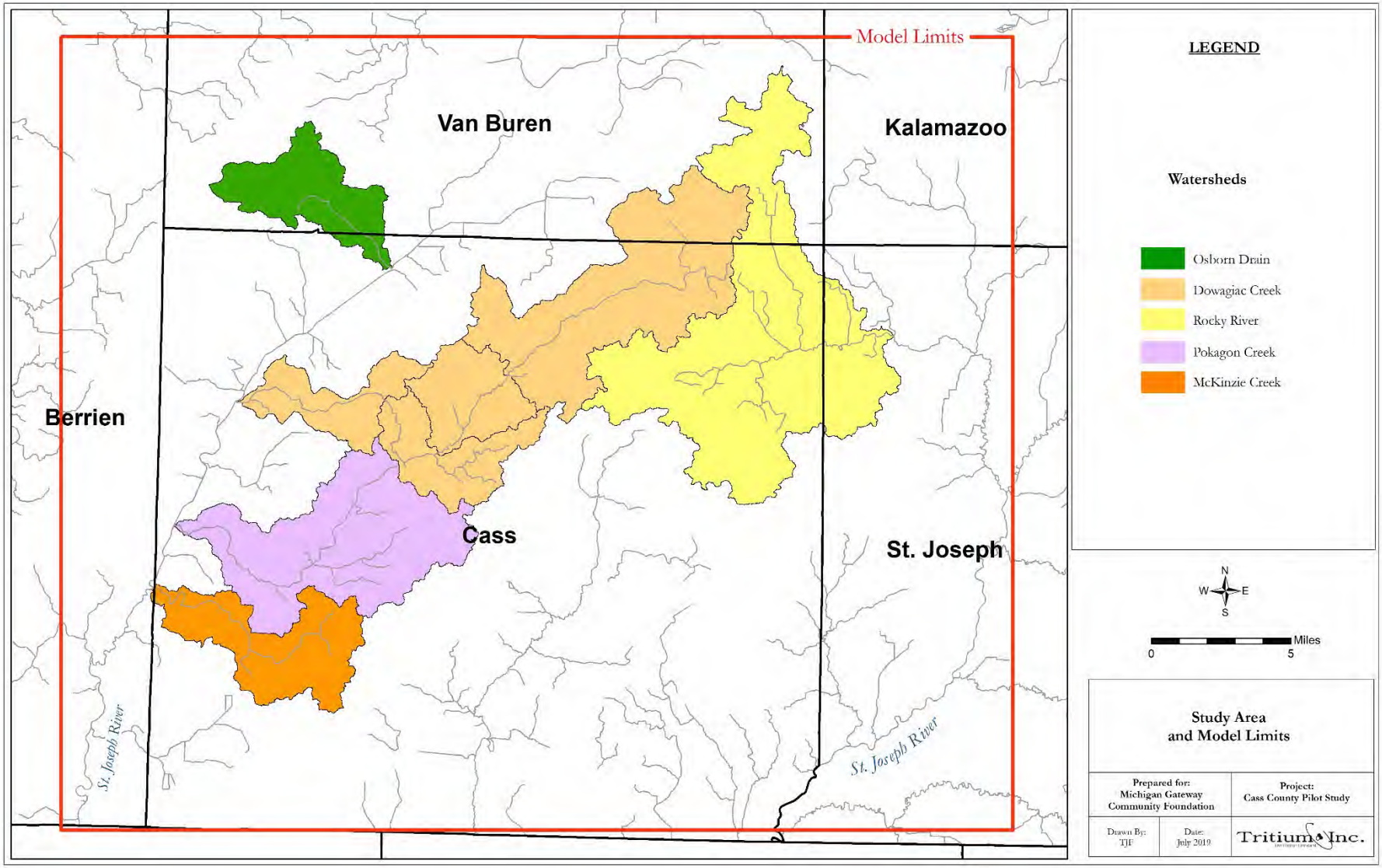
CASS COUNTY PILOT PROJECT

1. DATA COLLECTION
2. STREAMFLOW DEPLETION MODELING
3. TRANSFERABLE TECHNOLOGY



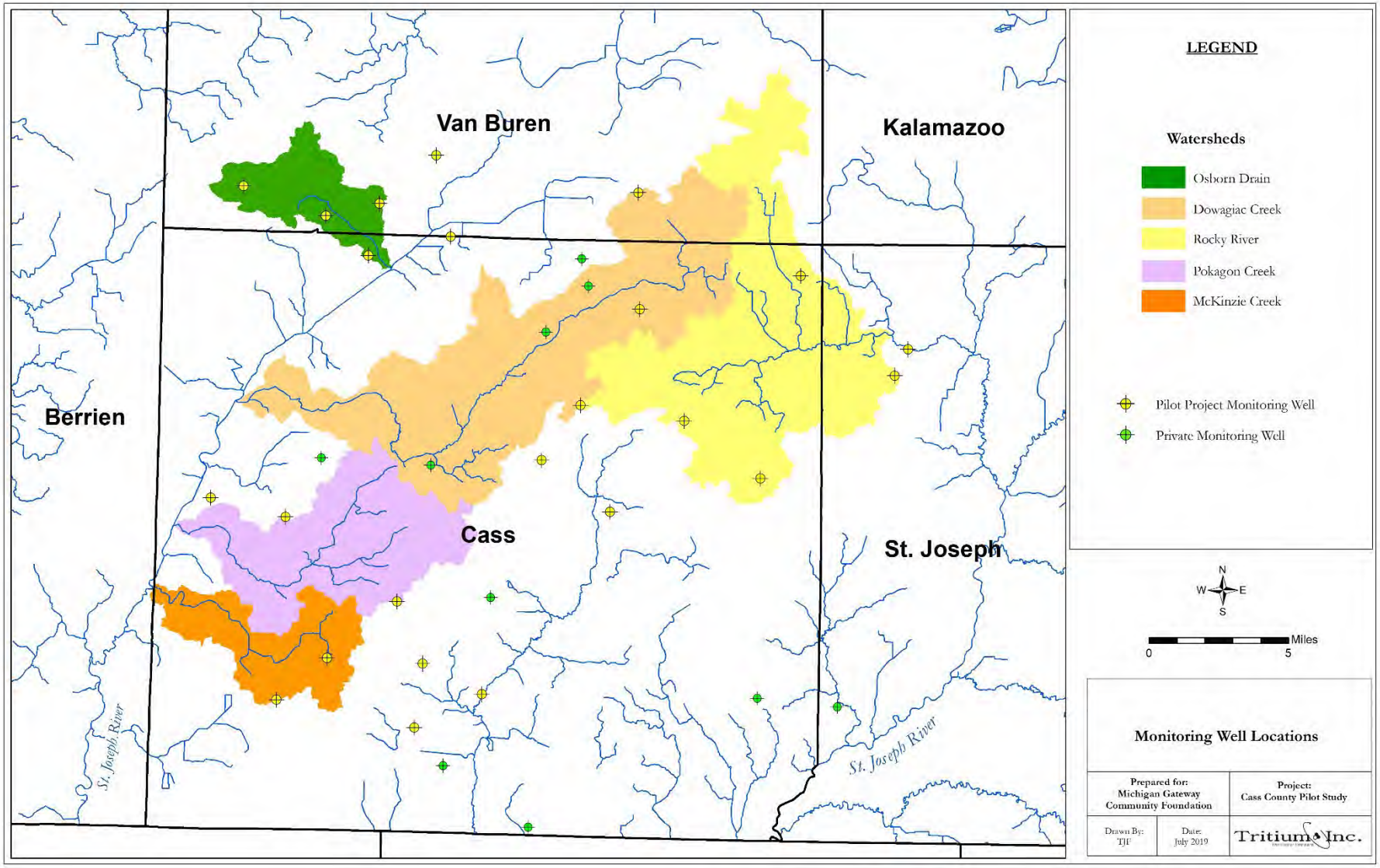
WORK PLAN VERSION 7

"The study area will be subdivided to facilitate the creation of four groundwater flow models and represent portions of five stressed watersheds in the county including: headwaters of the Dowagiac River, McKinzie Creek, Osborn Drain, Pokagon Creek, and southern headwaters of the Rocky River."



FINAL WATERSHED MANAGEMENT AREAS OF INTEREST

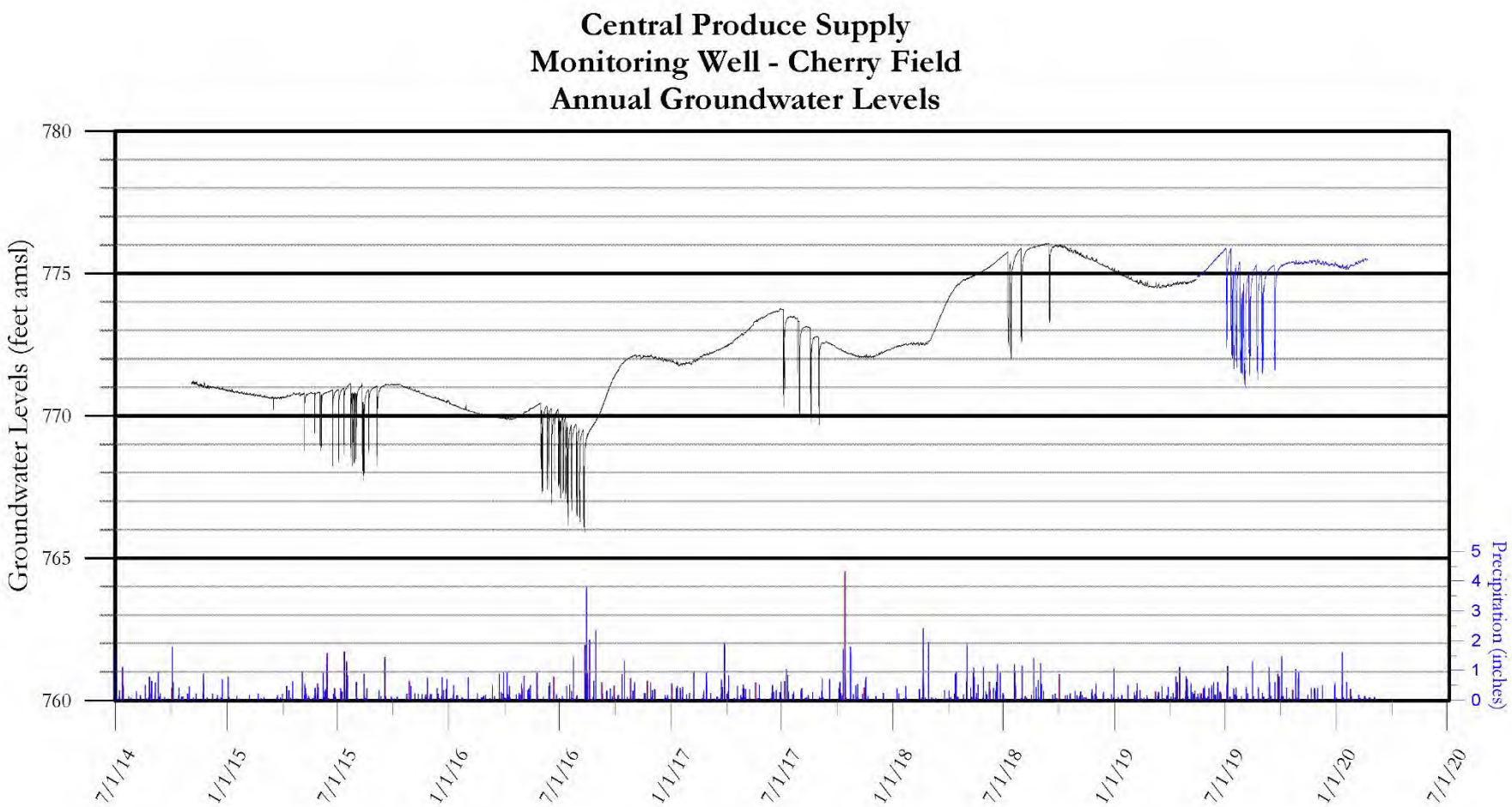
MONITORING WELLS
DRILLING
AQUIFER TESTS
WATER LEVEL DATA


Van Buren
Kalamazoo
Berrien
Cass
St. Joseph
St. Joseph River
St. Joseph River
LEGEND
Watersheds
Osborn Drain
Dowagiac Creek
Rocky River
Pokagon Creek
McKinzie Creek
Pilot Project Monitoring Well
Private Monitoring Well
N
W
E
S
Miles
0
5
Monitoring Well Locations
Prepared for:
Michigan Gateway
Community Foundation
Project:
Cass County Pilot Study
Drawn By:
TJF
Date:
July 2019
Tritium Inc.

CONTINUOUS WATER LEVEL MEASUREMENTS

MANUAL WATER LEVEL MEASUREMENTS

ULTRA-SONIC FLOW CHECK

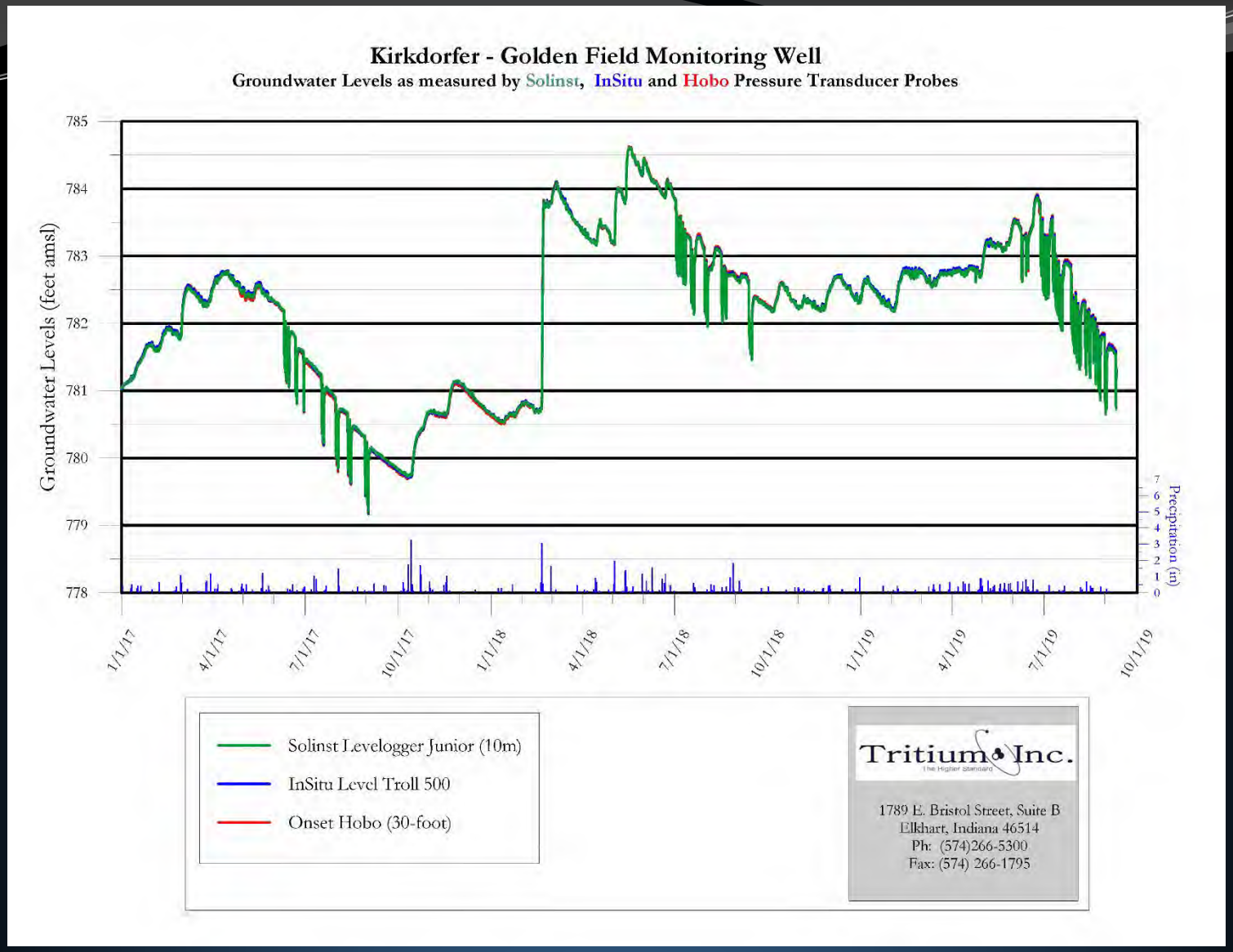

Central Produce Supply
Monitoring Well - Cherry Field
Annual Groundwater Levels
Groundwater Levels (feet amsl)
780
775
770
765
760
Precipitation (inches)
5
4
3
2
1
0
7/1/14
1/1/15
7/1/15
1/1/16
7/1/16
1/1/17
7/1/17
1/1/18
7/1/18
1/1/19
7/1/19
1/1/20
7/1/20

WATER LEVEL MEASUREMENT ACCURACY

What accuracy is needed?

What is a significant water level change?

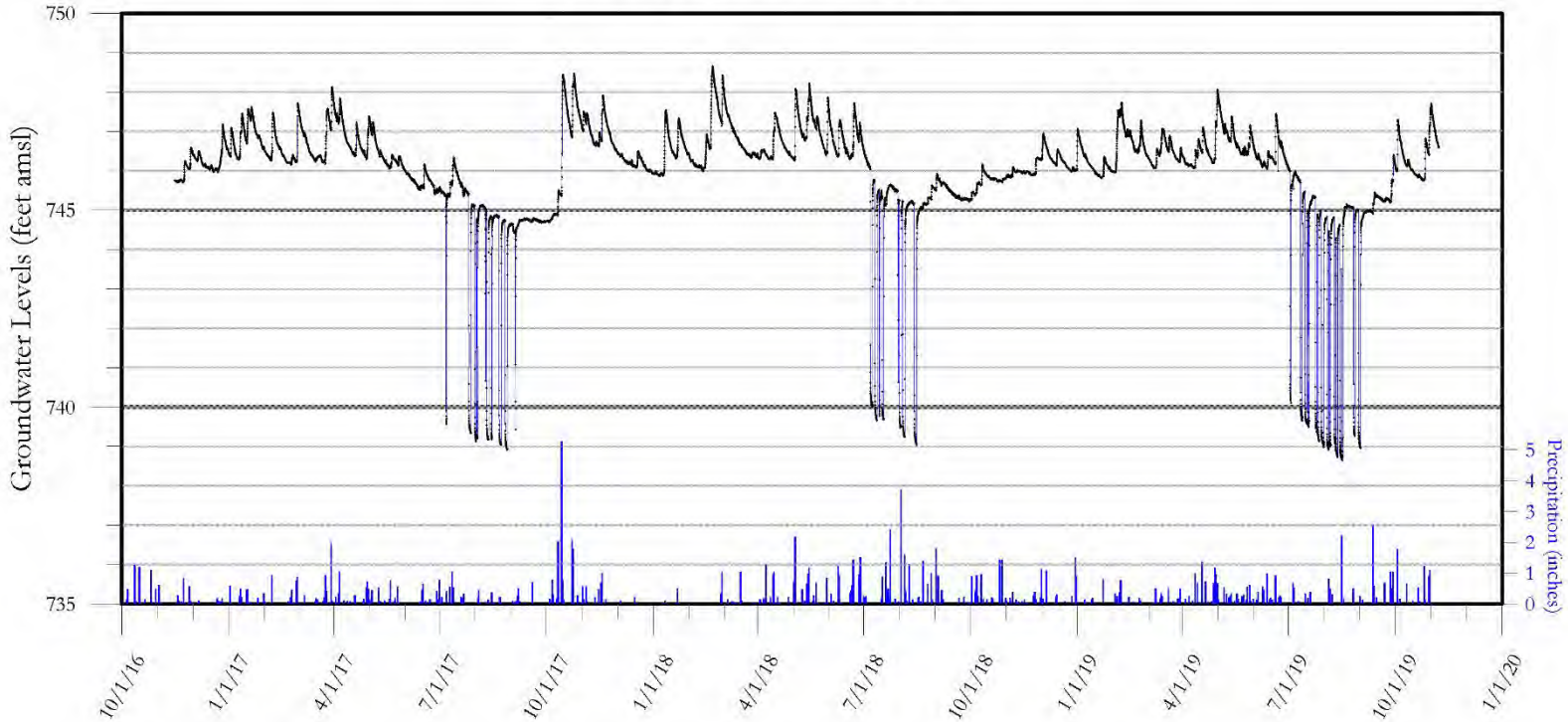
How accurate can we predict?



Three common brands of transducers in the same well

AVERAGE DIFFERENCE OF LESS THAN 1/4”

Berrybrook Farms
Monitoring Well - Bainbridge East (Deep)
Annual Groundwater Levels



Project: Cass County Assessment Pilot Project

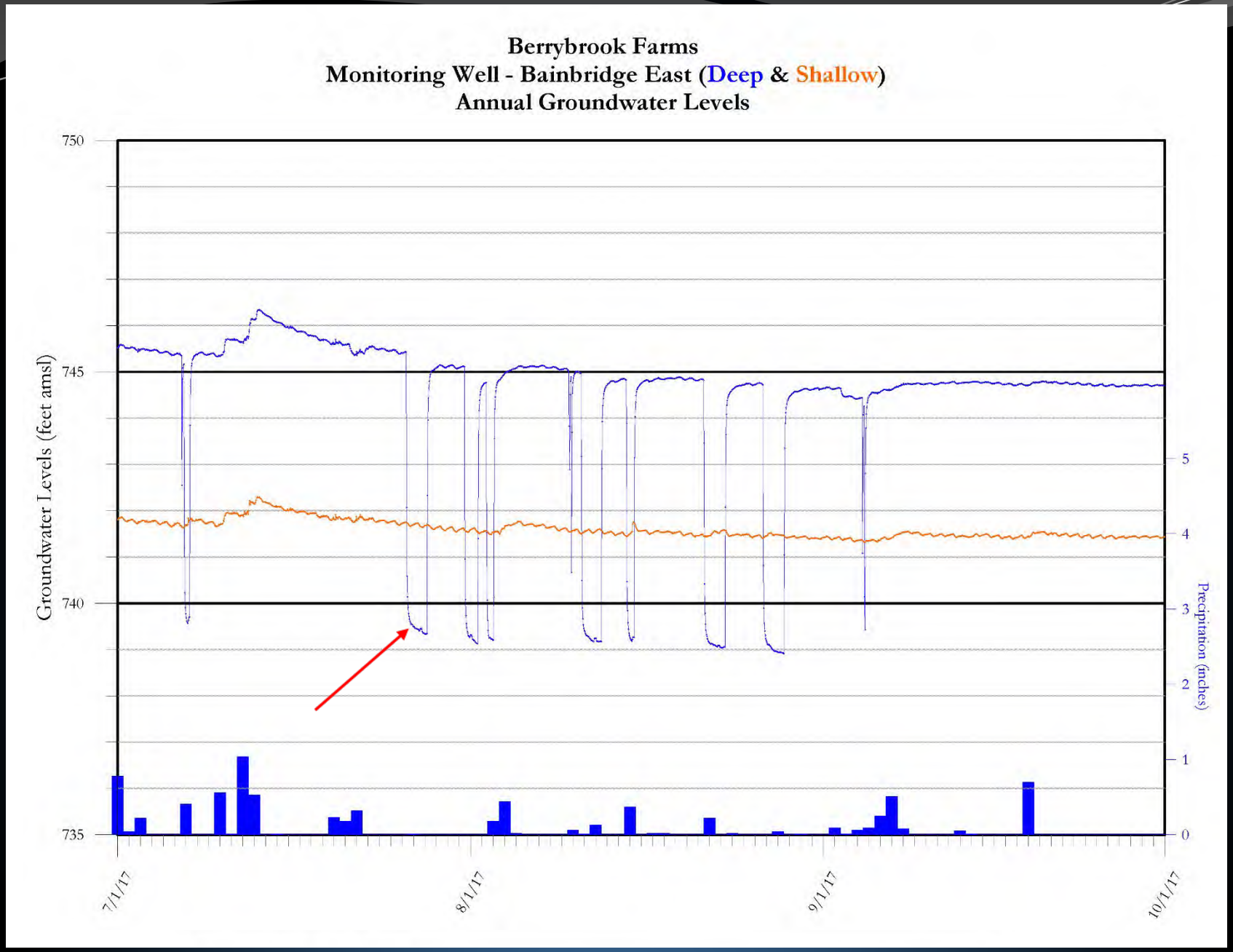
Irrigation Well
Depth: 80 feet
Static: n/a
Screen: 60-80 feet

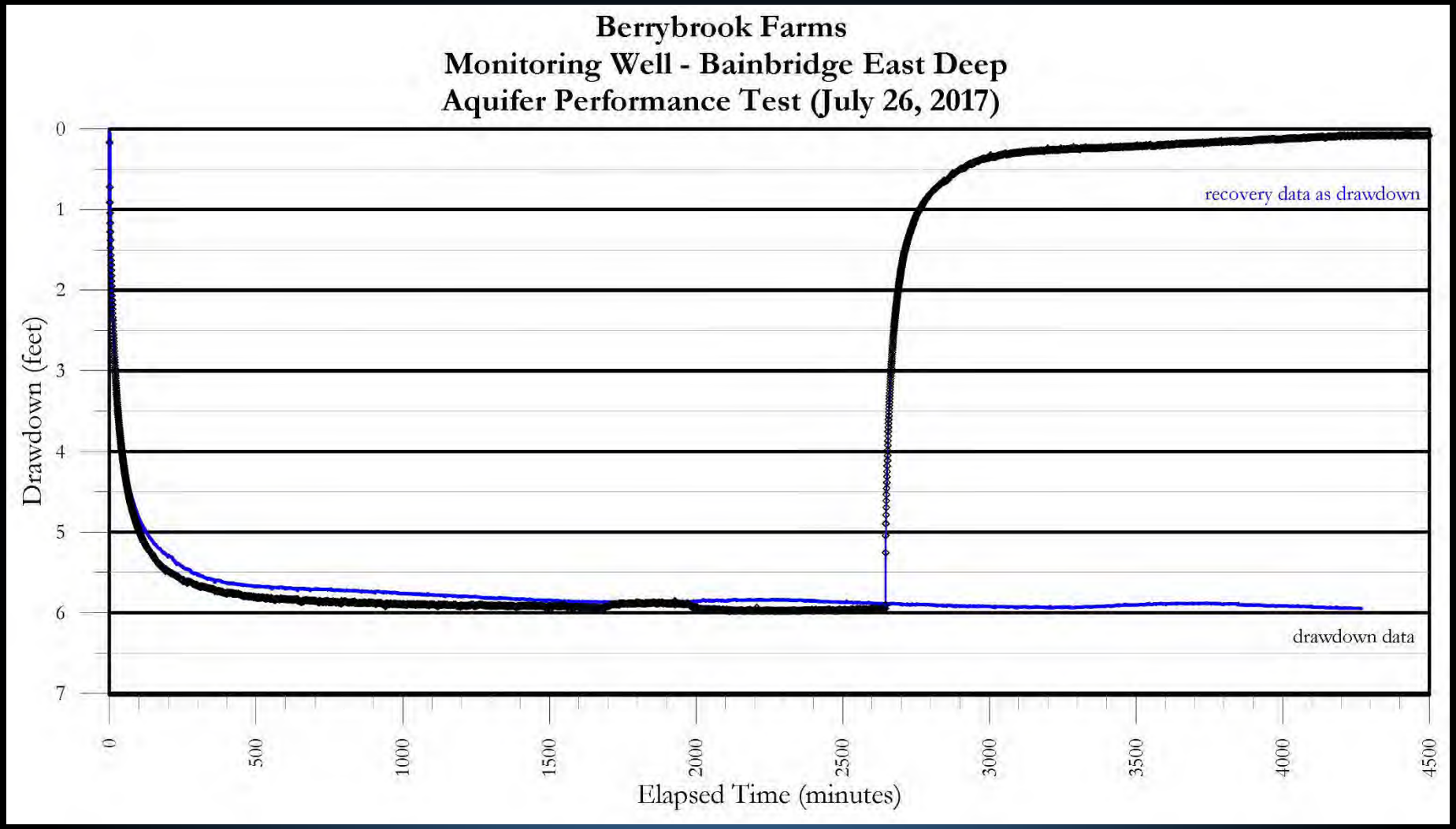
Monitoring Well
Depth: 75 feet
Static: 4 feet
Screen: 71-75 feet
Radial Distance: 90 feet

Measured Pumping Rates
Maximum: 950 gpm
Span only: n/a gpm
End Gun: n/a gpm

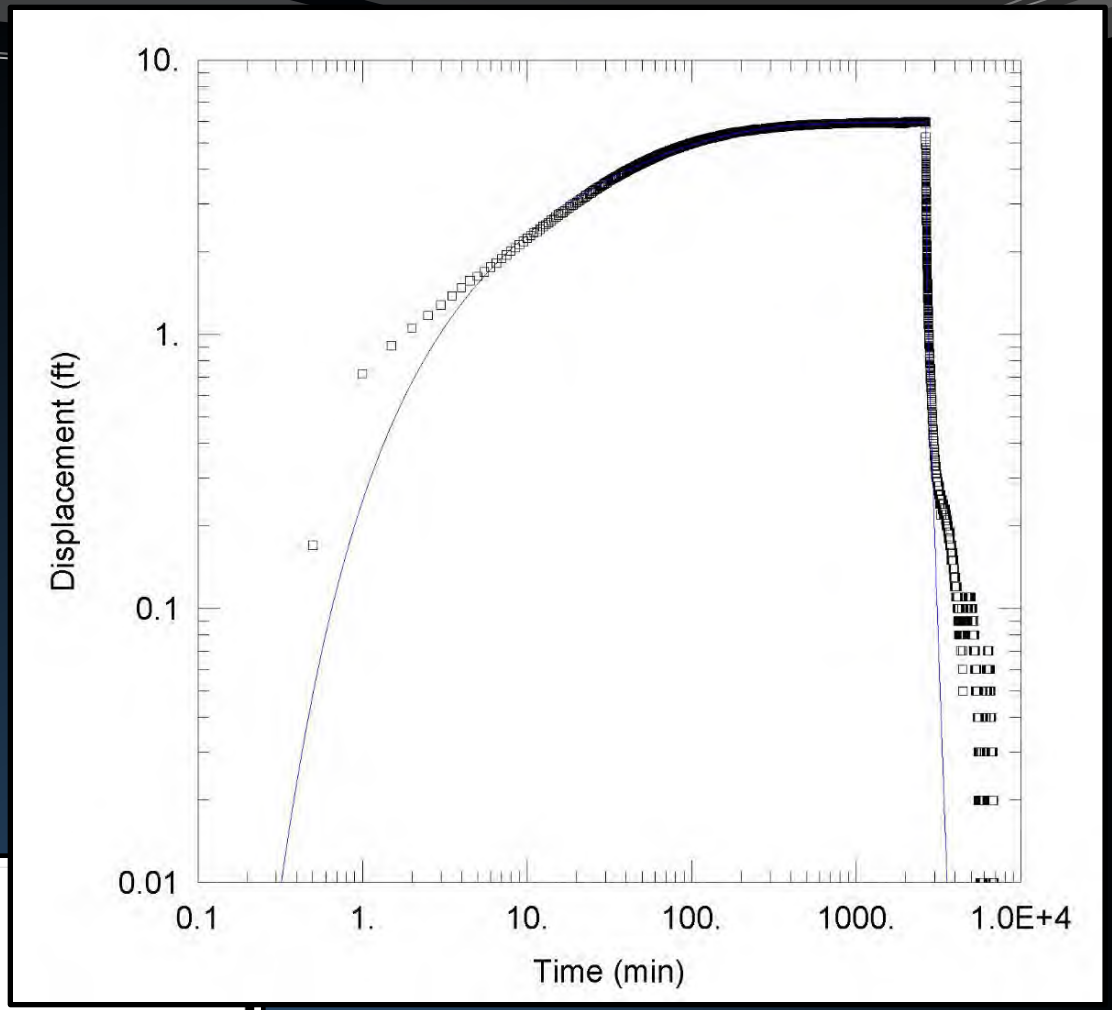
Weather Station
KMIDOWAG3

Tritium Inc.
The Higher Standard
1789 E. Bristol Street, Suite B
Elkhart, Indiana 46514
Ph: (574)266-5300
Fax: (574) 266-1795


Berrybrook Farms
Monitoring Well - Bainbridge East (Deep & Shallow)
Annual Groundwater Levels
Groundwater Levels (feet amsl)
750
745
740
735
Precipitation (inches)
5
4
3
2
1
0
7/1/17
8/1/17
9/1/17
10/1/17


Berrybrook Farms
Monitoring Well - Bainbridge East Deep
Aquifer Performance Test (July 26, 2017)
Drawdown (feet)
0
1
2
3
4
5
6
7
recovery data as drawdown
drawdown data
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Elapsed Time (minutes)

AQUIFER TEST ANALYSES (AQTESOLV)



PROJECT INFORMATION

Company: Tritium, Inc.
Client: Berrybrook Farms
Project: 201701
Location: Bainbridge East Deep
Test Well: Iw
Test Date: 7/26/2017

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Iw	12673940	212255

Observation Wells

Well Name	X (ft)	Y (ft)
Mw	12673901	212174

SOLUTION

Aquifer Model: Leaky
T = 1.07E+4 ft^2/day
r/B = 0.13
b = 22. ft

Solution Method: Hantush-Jacob
S = 0.004134
Kz/Kr = 0.1

2,646 minutes
at 950 gpm

PREDICTED DRAWDOWN

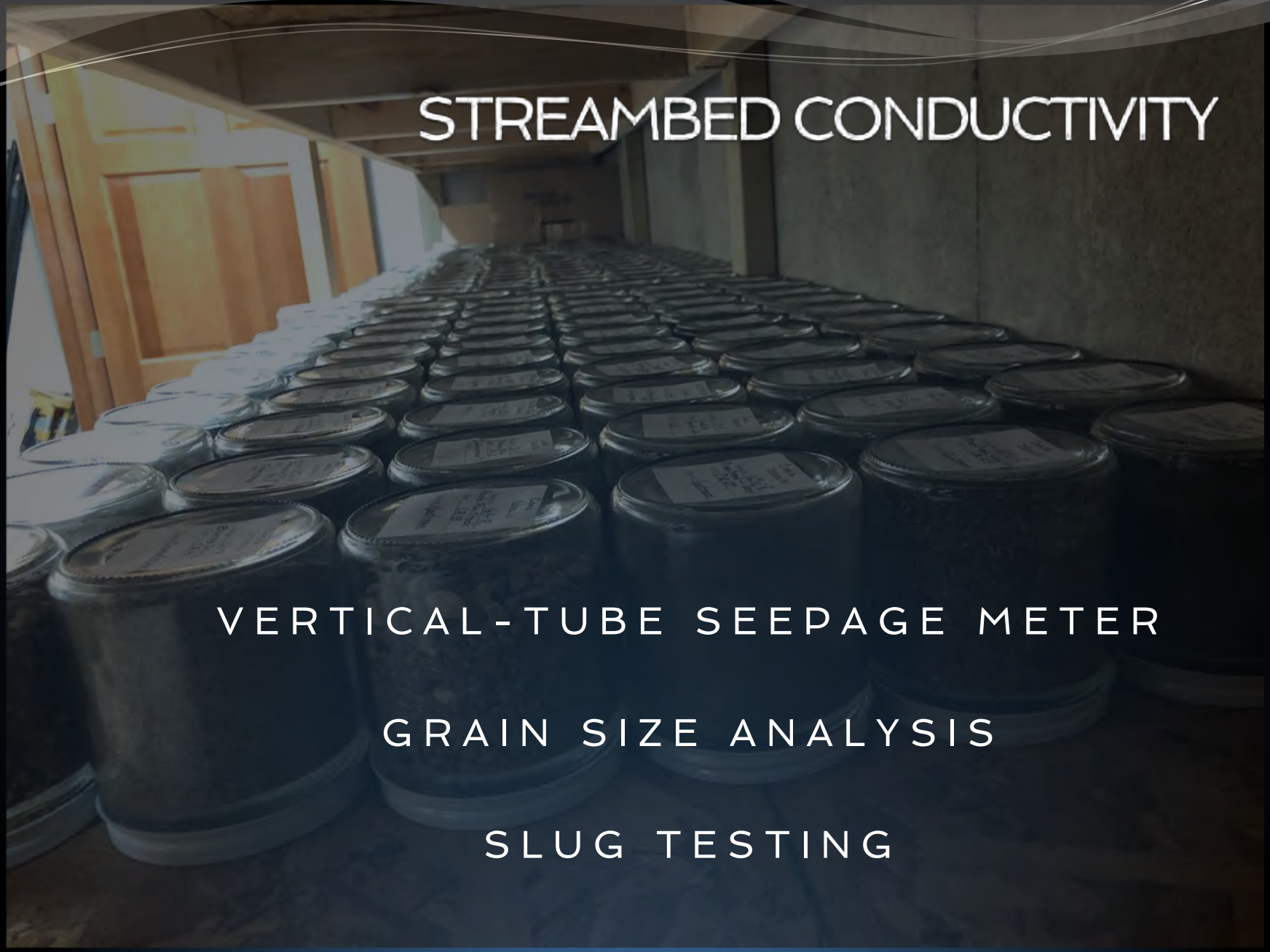
Distance (feet)	Drawdown (feet)
500	3.88
1,000	2.28
2,000	1.00

MONITORING WELL AND AQUIFER TEST LESSONS

1. One monitoring well is sufficient
2. Irrigation Pivots are effective tools
    a. distribute the pumped water
    b. variable pumping rates
    c. repeatable tests
3. 24 hours is sufficient length to derive transmissivity and storage values
4. Nested monitoring wells are effective in multi-layer systems
5. Long-term water level data is invaluable

STREAM TESTING

STREAMBED CONDUCTIVITY
AND
STREAM DISCHARGE

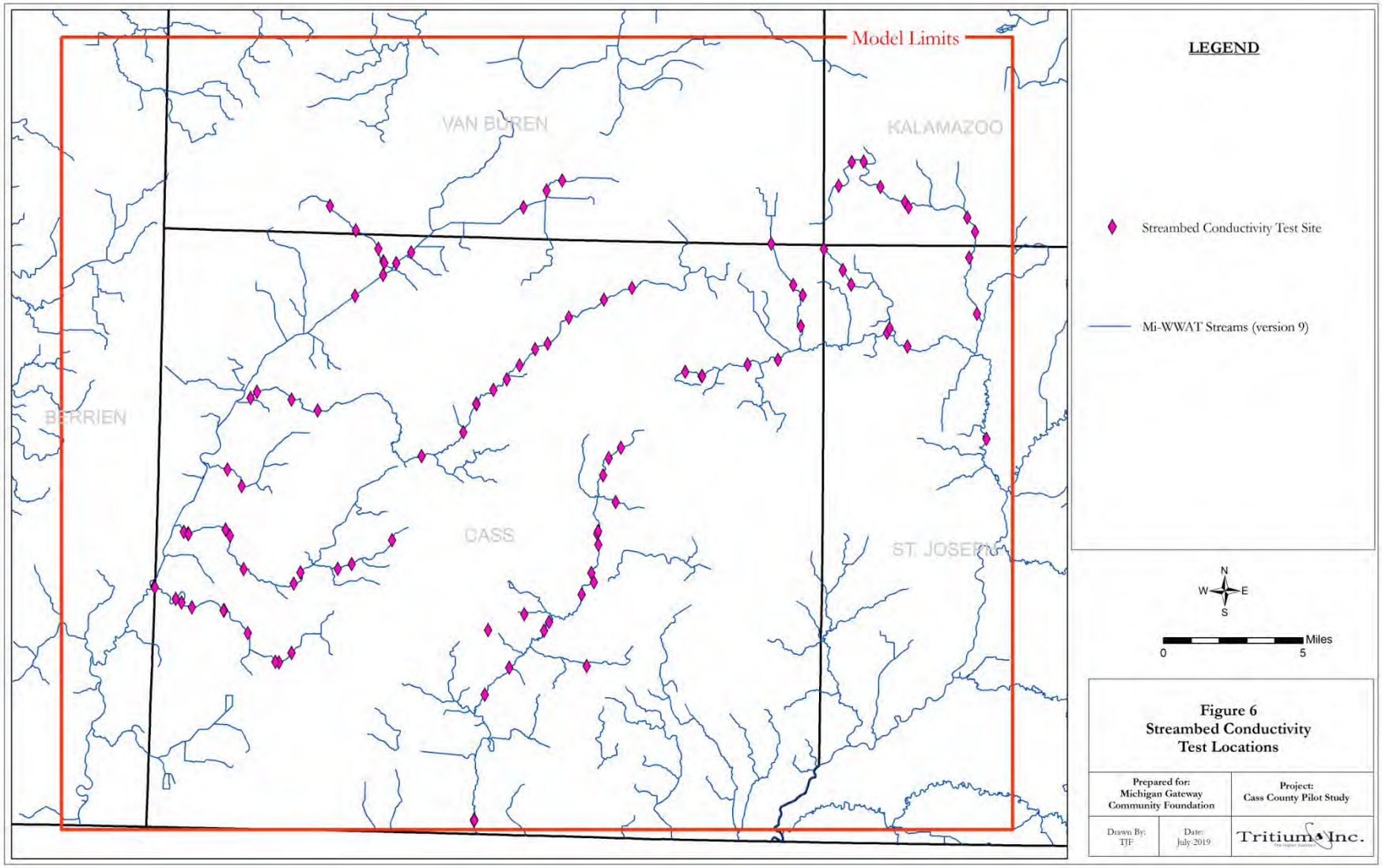


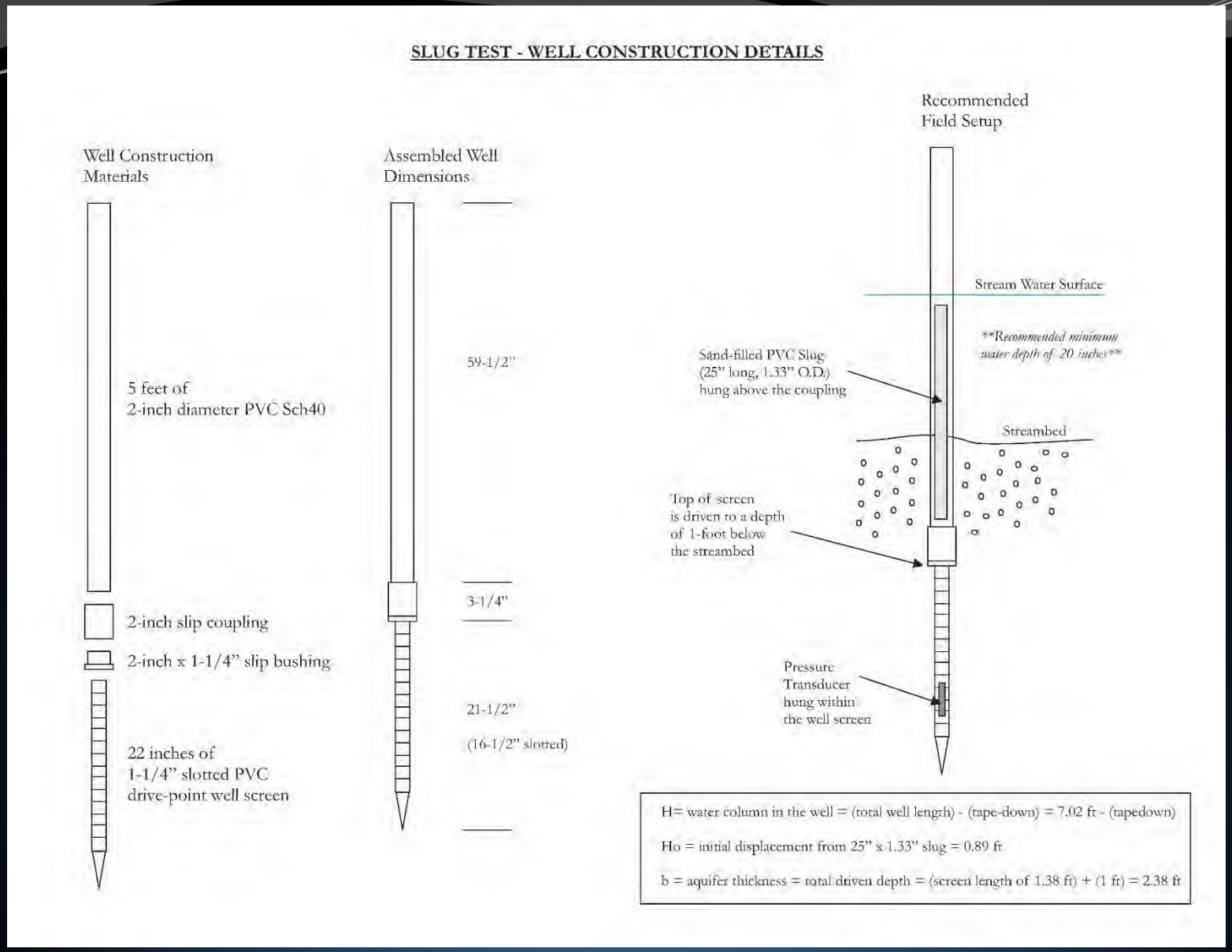
STREAMBED CONDUCTIVITY

VERTICAL-TUBE SEEPAGE METER

GRAIN SIZE ANALYSIS

SLUG TESTING

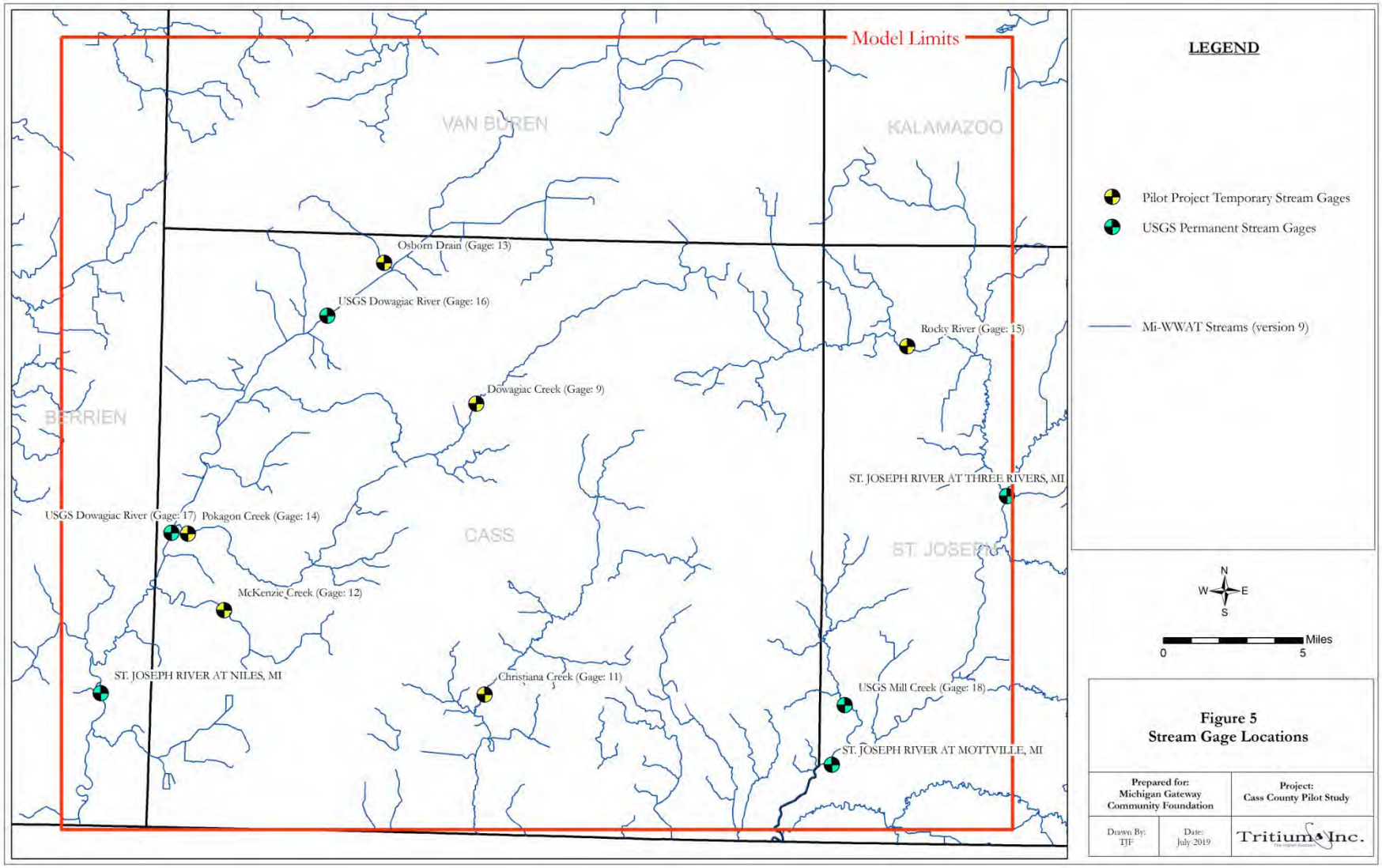

Model Limits
VAN BUREN
KALAMAZOO
BERRIEN
CASS
ST. JOSEPH
LEGEND
Streambed Conductivity Test Site
Mi-WWAT Streams (version 9)
N
W
E
S
Miles
0
5
Figure 6
Streambed Conductivity
Test Locations
Prepared for:
Michigan Gateway
Community Foundation
Project:
Cass County Pilot Study
Drawn By:
TJF
Date:
July 2019
Tritium Inc.

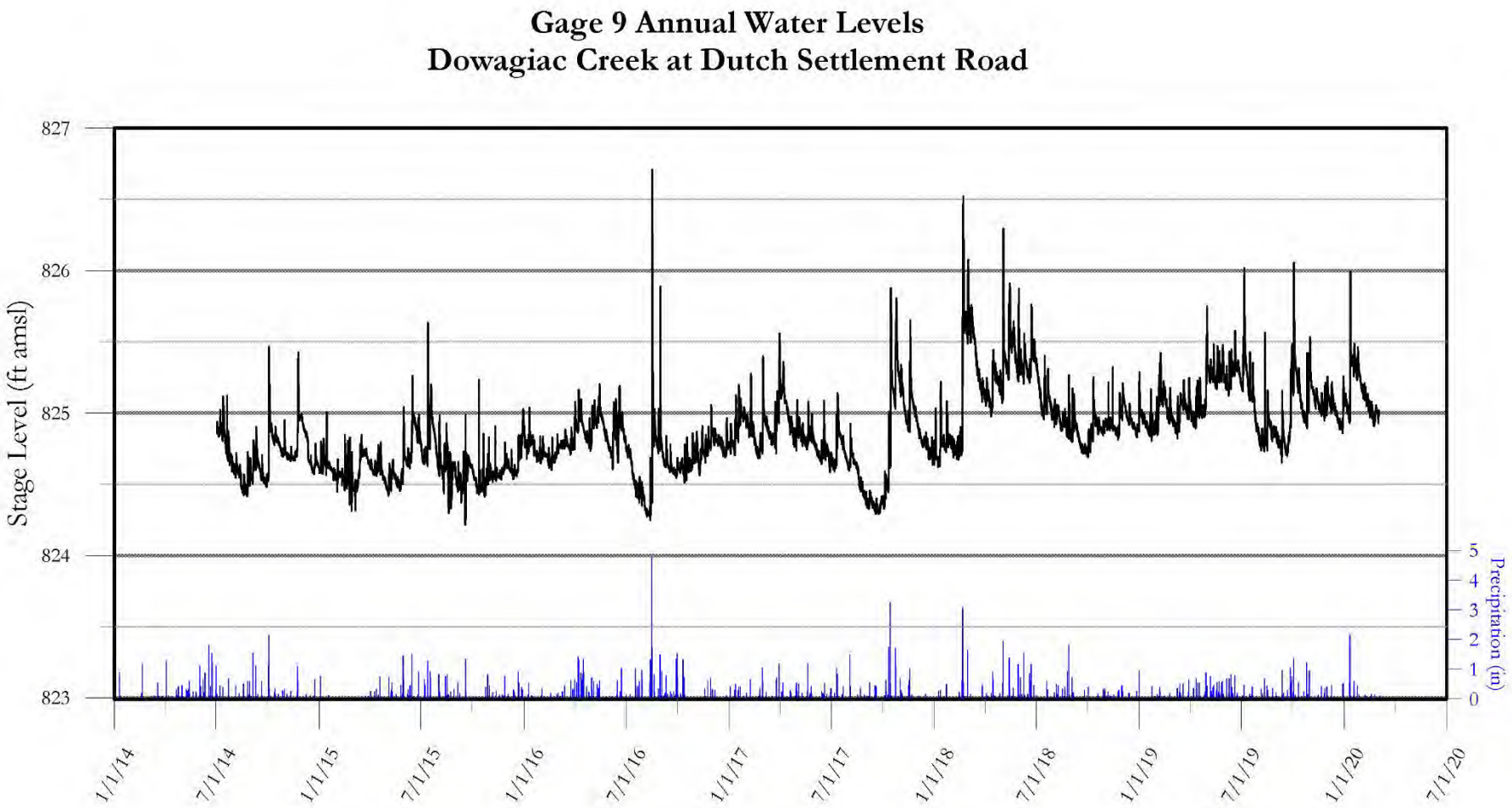


SLUG TESTING

SIGNIFICANT LESSONS

- There was no statistical correlation between the three types of tests.
- Grain size analysis and Slug testing are commonly used methods, but neither represents vertical conductivity.
- Gaining or losing conditions are important
- Rising head tests should be used due to layering, fine sediments, and organics
- Barrel-type seepage meters will not work in these conditions
- Vertical Tube Meters are highly recommended based on accuracy, representative of K_v, and efficiency of use


Model Limits
VAN BUREN
KALAMAZOO
BERRIEN
CASS
ST. JOSEPH
Osborn Drain (Gage: 13)
USGS Dowagiac River (Gage: 16)
Rocky River (Gage: 15)
Dowagiac Creek (Gage: 9)
ST. JOSEPH RIVER AT THREE RIVERS, MI
USGS Dowagiac River (Gage: 17)
Pokagon Creek (Gage: 14)
McKenzie Creek (Gage: 12)
ST. JOSEPH RIVER AT NILES, MI
Christiana Creek (Gage: 11)
USGS Mill Creek (Gage: 18)
ST. JOSEPH RIVER AT MOTTVILLE, MI
LEGEND
Pilot Project Temporary Stream Gages
USGS Permanent Stream Gages
Mi-WWAT Streams (version 9)
N
W
E
S
Miles
0
5
Figure 5
Stream Gage Locations
Prepared for:
Michigan Gateway
Community Foundation
Project:
Cass County Pilot Study
Drawn By:
TJF
Date:
July 2019
Tritium Inc.

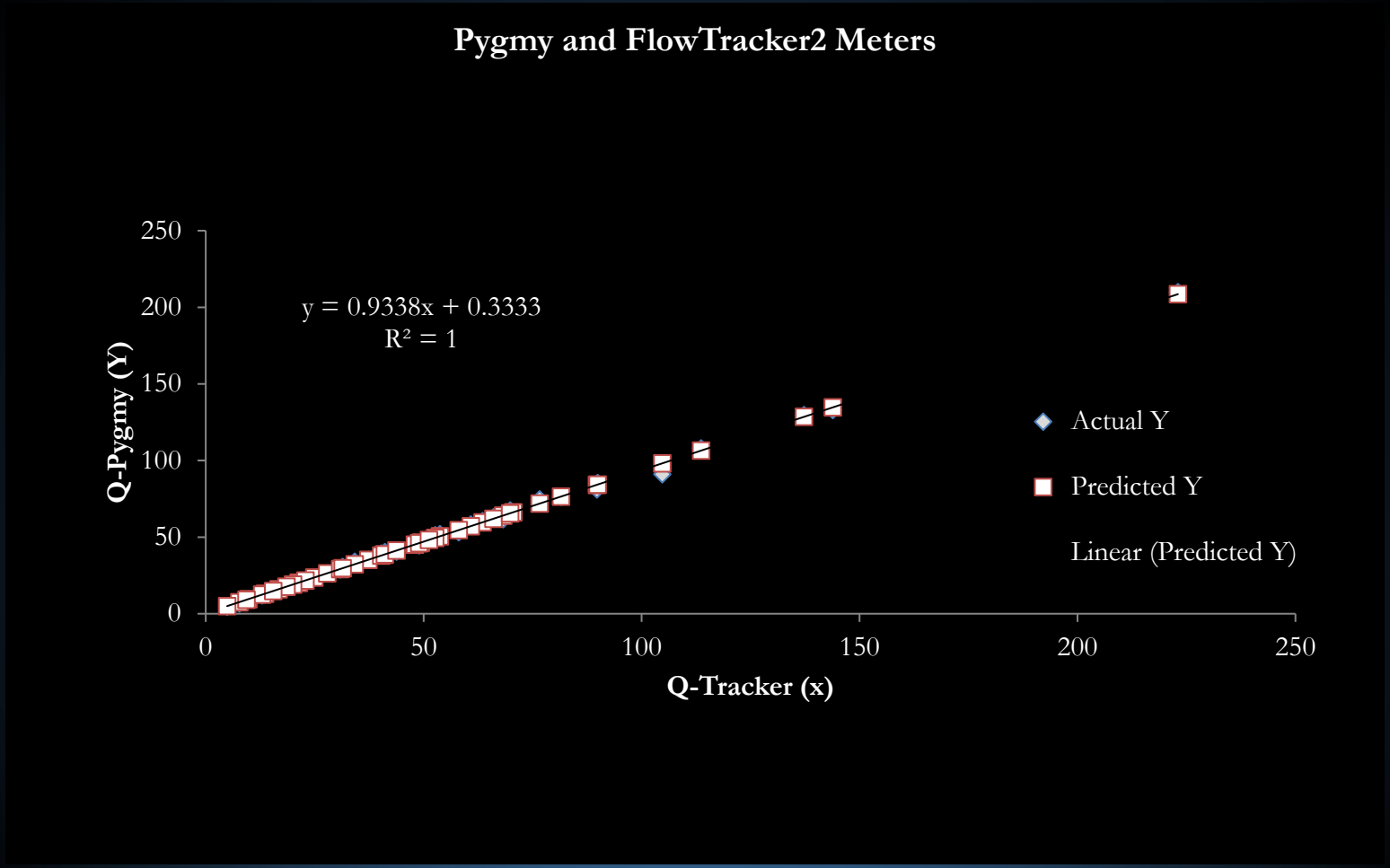

Gage 9 Annual Water Levels
Dowagiac Creek at Dutch Settlement Road
Stage Level (ft amsl)
827
826
825
824
823
Precipitation (in)
5
4
3
2
1
0
1/1/14
7/1/14
1/1/15
7/1/15
1/1/16
7/1/16
1/1/17
7/1/17
1/1/18
7/1/18
1/1/19
7/1/19
1/1/20
7/1/20

FLOWTRACKER2
$10,000

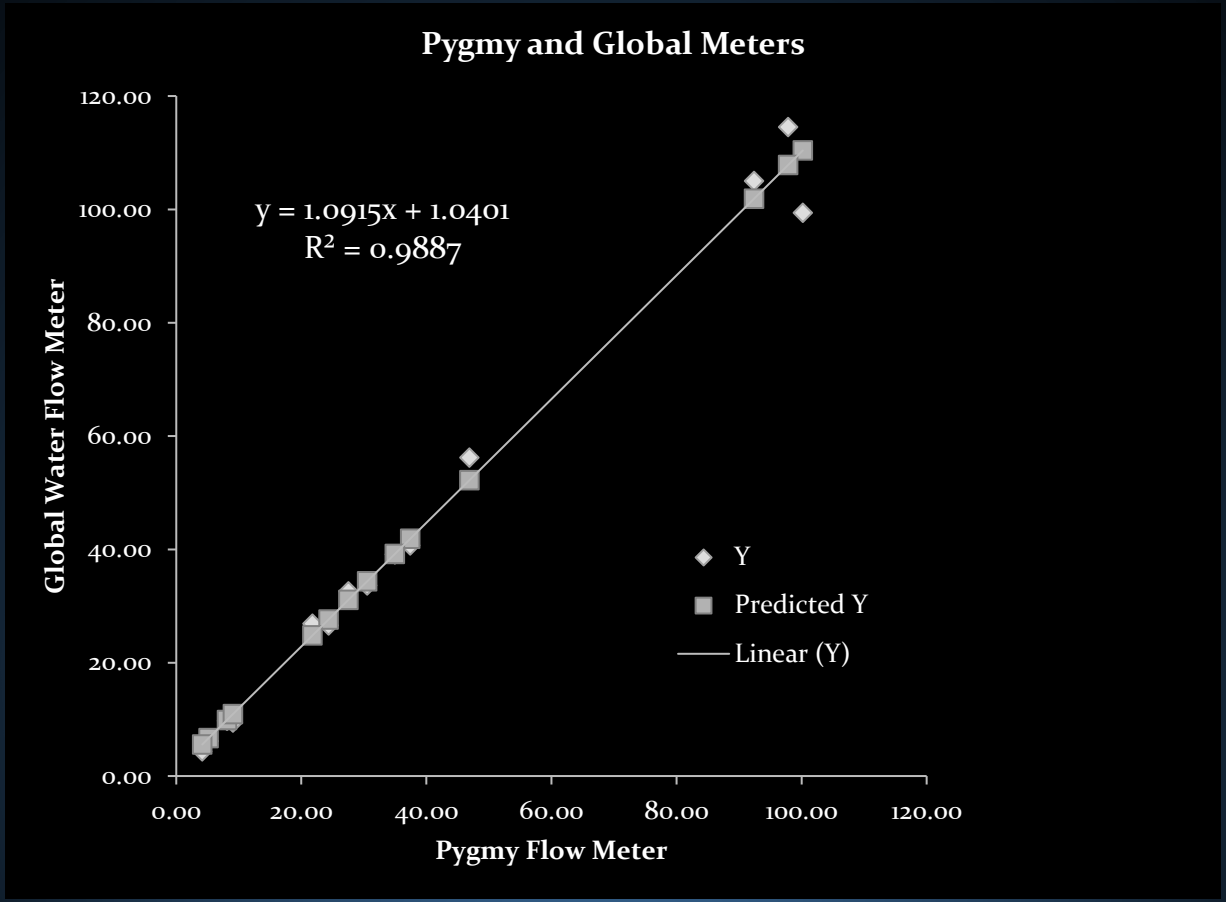
GLOBAL WATER
$1,000

USGS PYGMY
$5,000

LINEAR REGRESSION



LINEAR REGRESSION



SIGNIFICANT LESSONS

1. GOOD REGRESSION EQUATIONS BETWEEN ALL METERS
2. GLOBAL WATER 17% HIGHER THAN PYGMY
3. PYGMY ABOUT 7% LOWER THAN FLOWTRACKER2
4. USGS STUDIES INDICATE DISCHARGE ACCURACY OF ABOUT 7% IS ACHIEVABLE BUT IS THE MINIMUM ERROR
5. PYGMY AND GLOBAL ARE WORSE IN COLD WEATHER
6. CAREFUL TO AVOID SURFACE WATER INTAKES, DAMS, BENDS, DEADFALLS, STREAMBED OBSTRUCTIONS
7. LONG-TERM STREAM STAGE DATA IS INVALUABLE
8. CRITICAL TO SUPERIMPOSE PRECIPITATION DATA

FIELD WORK SUMMARY

120 Streambed Conductivity Test Sites

135 Stream Discharge Measurements

30 new monitoring wells

50 aquifer performance tests

6 new stream gages

65 stream stage sites

51 active monitoring wells

25 million water level measurements

TRANSFERRABLE TECHNOLOGY

1. Streambed Conductivity Tests - Vertical Tube Seepage Meters
2. Stream Discharge – meter comparison
3. Pressure Transducers – three brands, two types
4. 1-minute and 15-minute measurement intervals
5. Water Level Accuracy of ½-inch (0.04 ft)
6. Single Monitoring Wells
7. 24-hour Aquifer Tests using Pivot Systems
8. Ultra-sonic flow meters for well pumping rates
9. Water level data QA/QC procedures and templates

QUARTERLY TECHNICAL COMMITTEE MEETINGS

Reviewed progress and products

Data transfer

Discussed methodologies and adjustments

FIELD DEMONSTRATION AND TRAINING DAYS

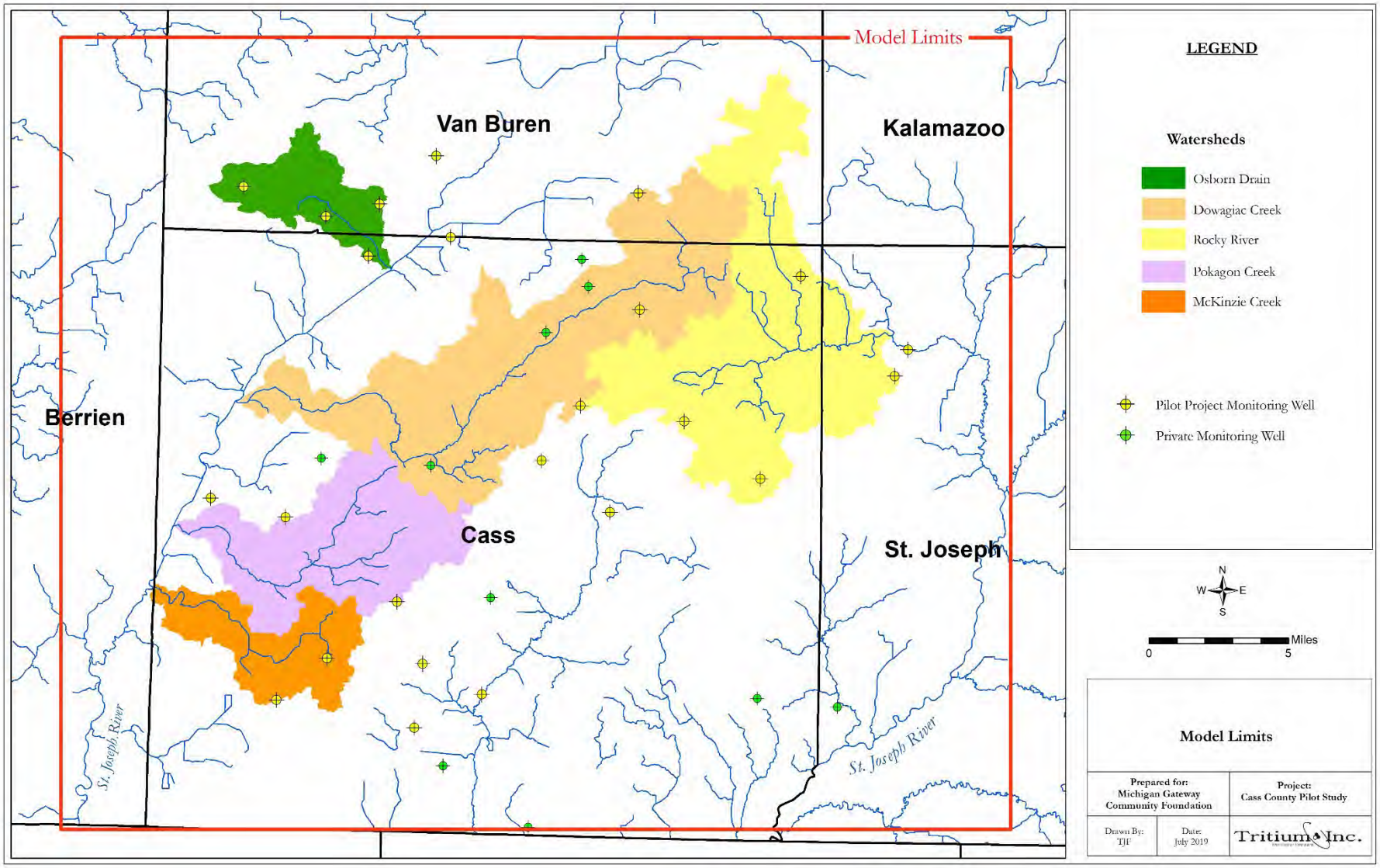
Mud-rotary Drilling (two days)

Stream discharge and streambed conductivity

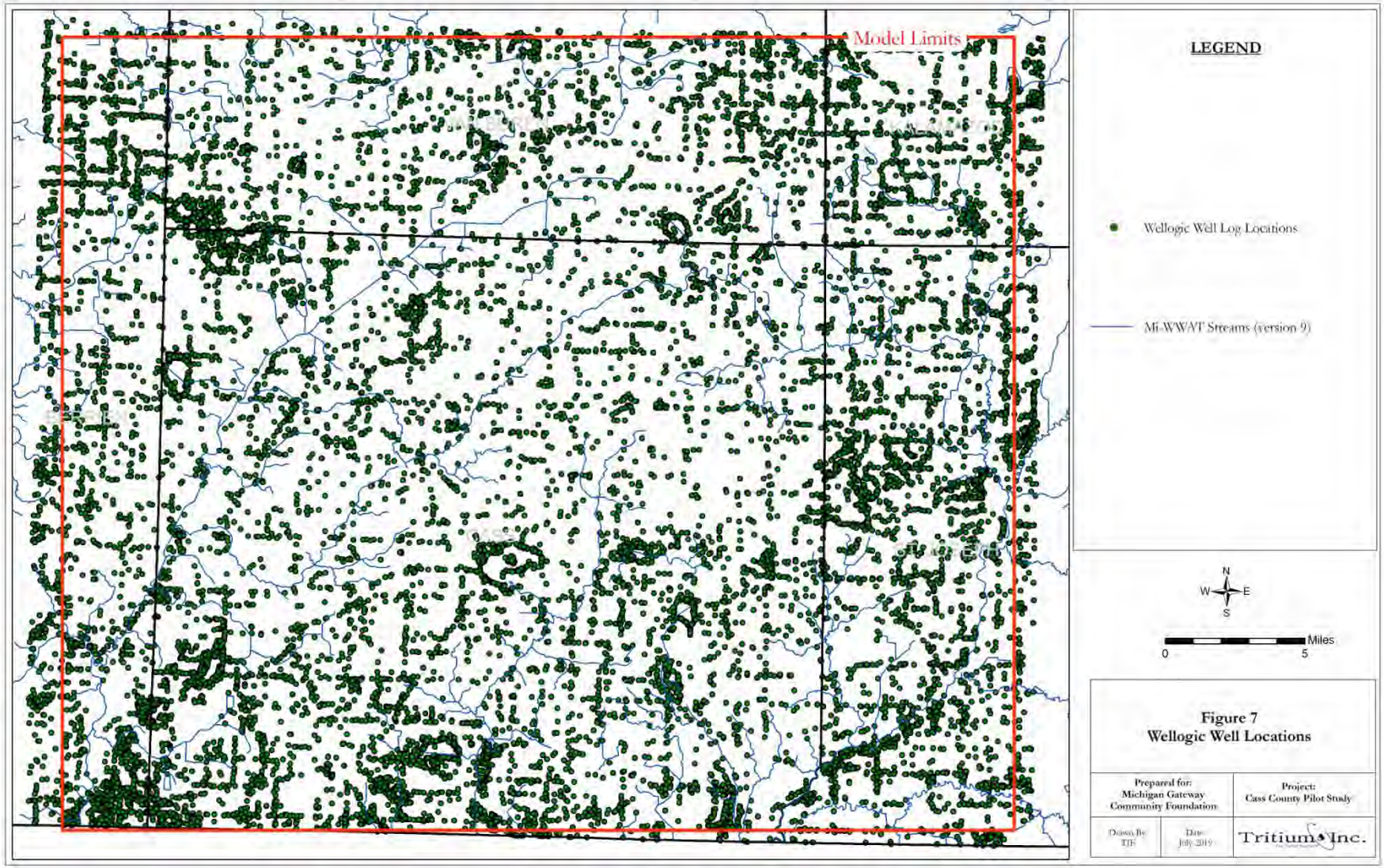
Monitoring well data collection and processing

GROUNDWATER FLOW MODEL

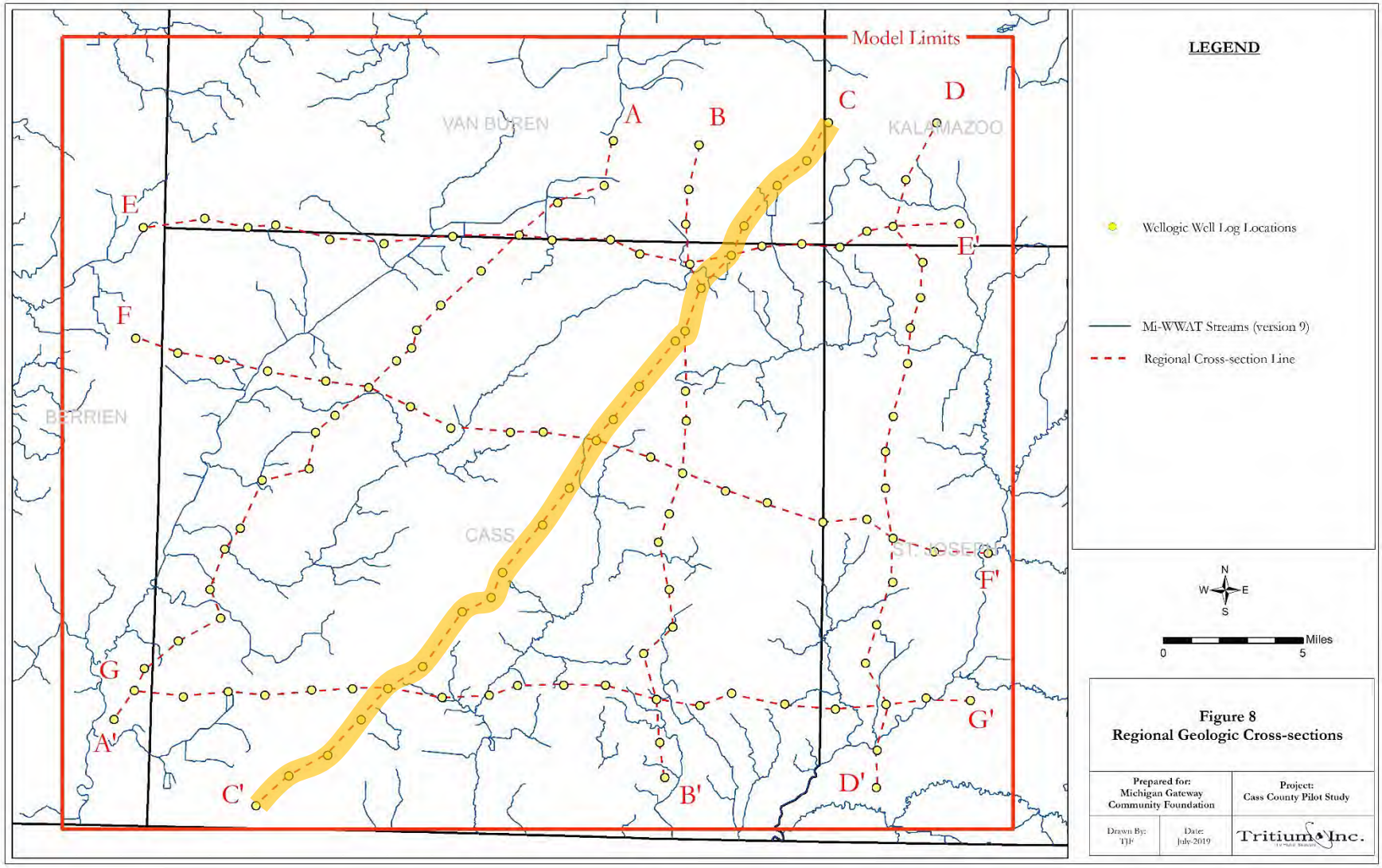
PURPOSE:	Estimate streamflow depletion from crop irrigation
GOAL:	Reasonable and representative model
MODEL TYPE:	Change model



WATERSHED MANAGEMENT AREAS OF INTEREST

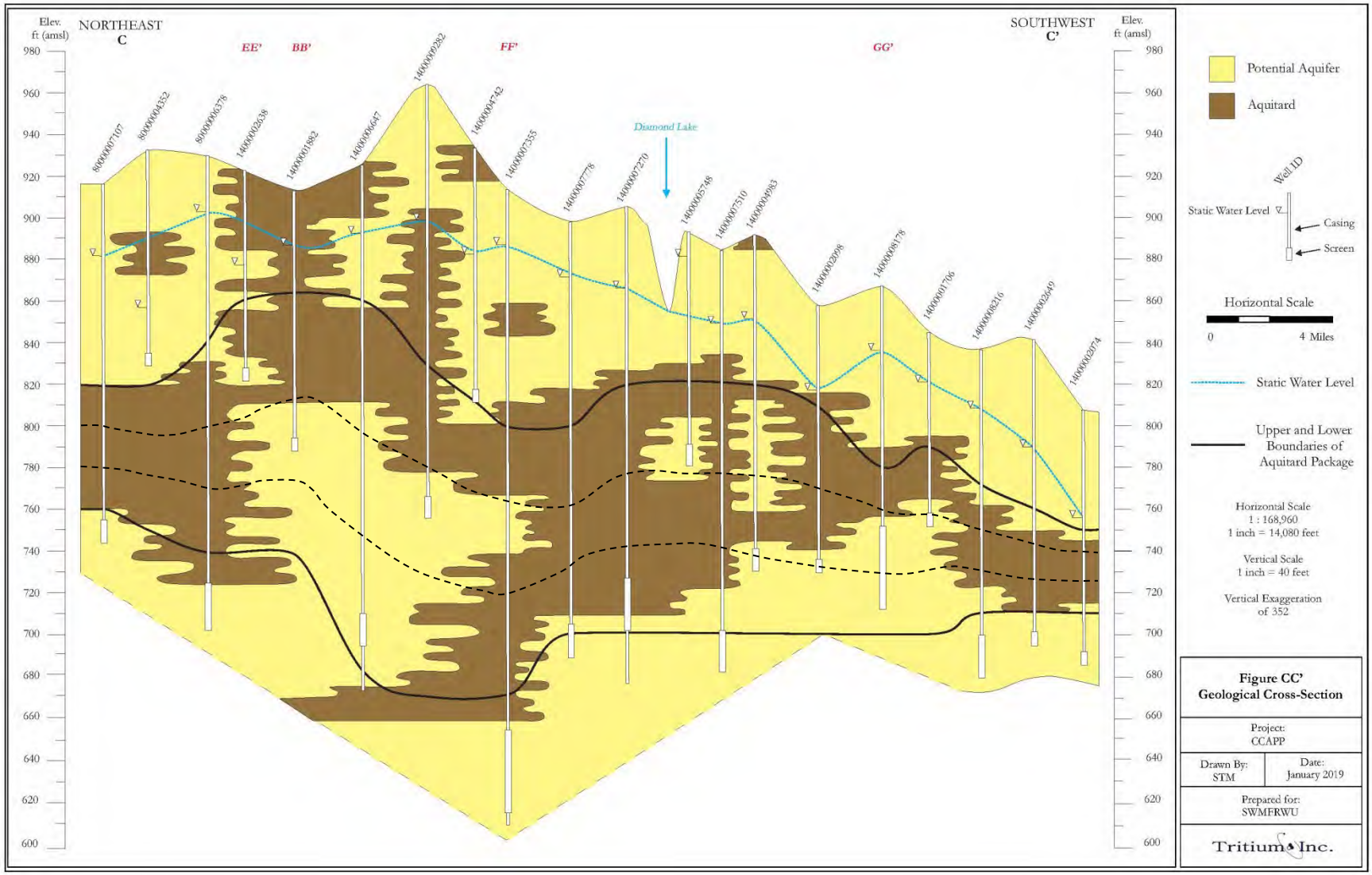

Model Limits
LEGEND
Wellogic Well Log Locations
Mi-WWAT Streams (version 9)
N
W
E
S
Miles
0
5
Figure 7
Wellogic Well Locations
Prepared for:
Michigan Gateway
Community Foundation
Project:
Cass County Pilot Study
Drawn By:
TJE
Date:
July 2019
Tritium Inc.

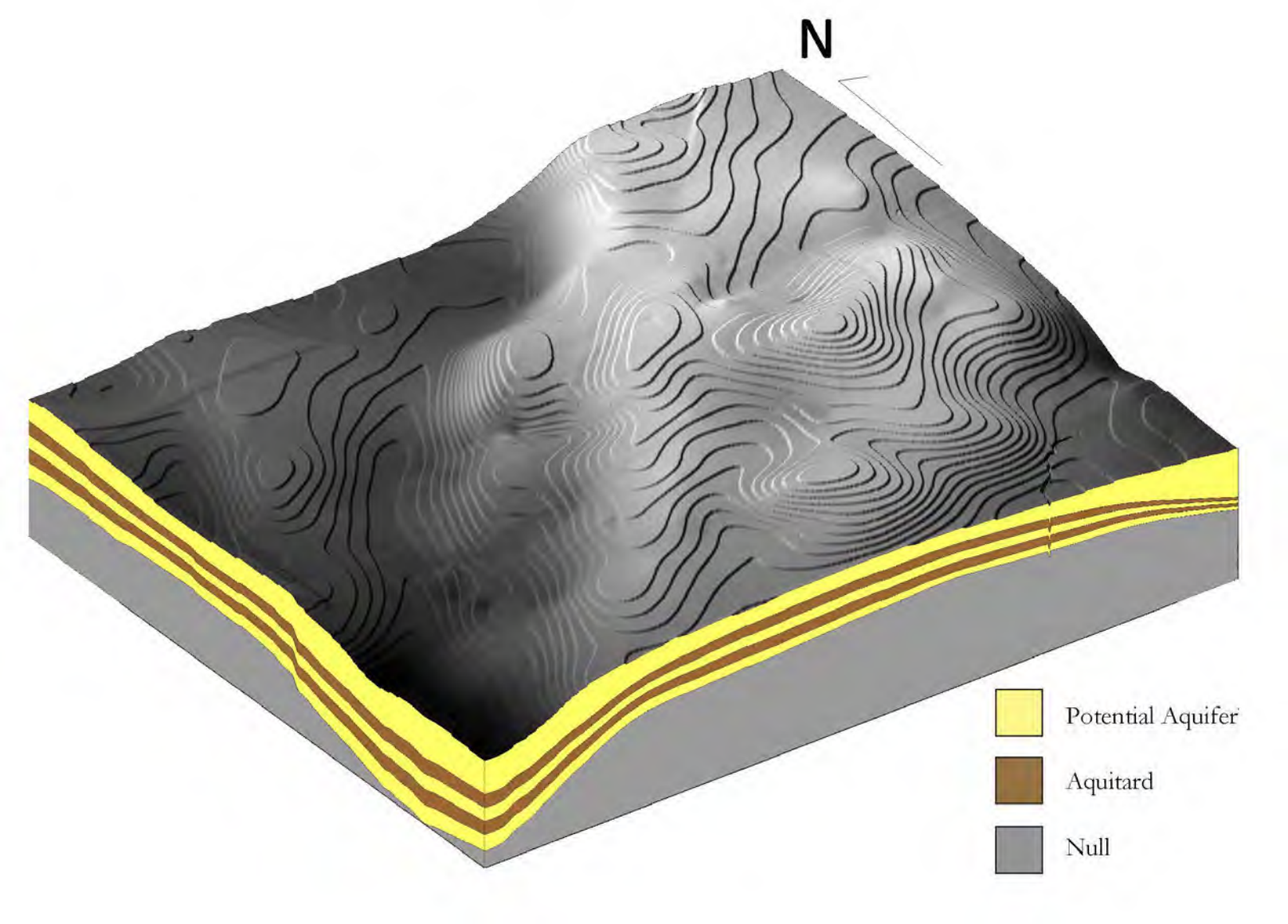
21,000 LOGS



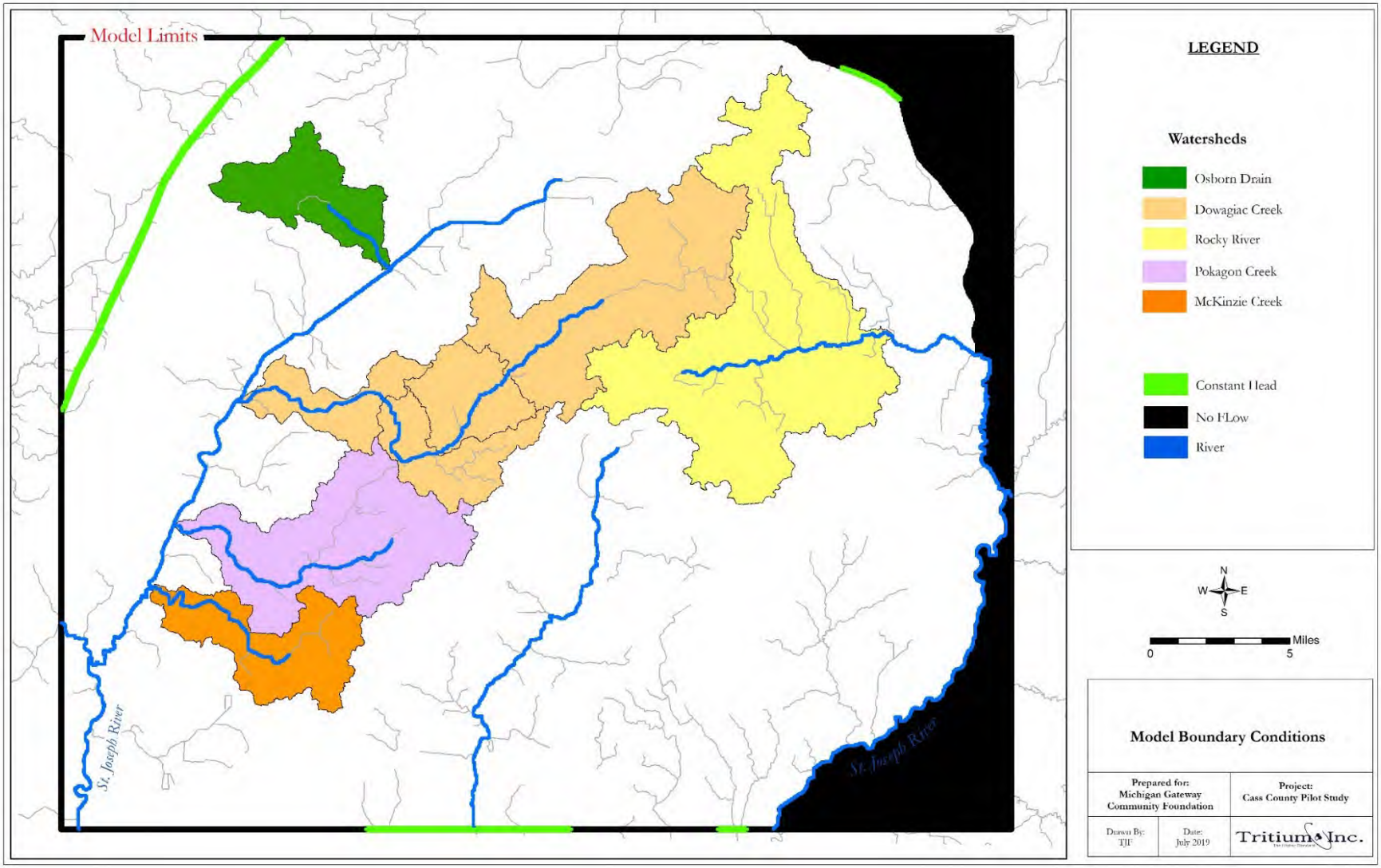
7 REGIONAL

80 LOCAL

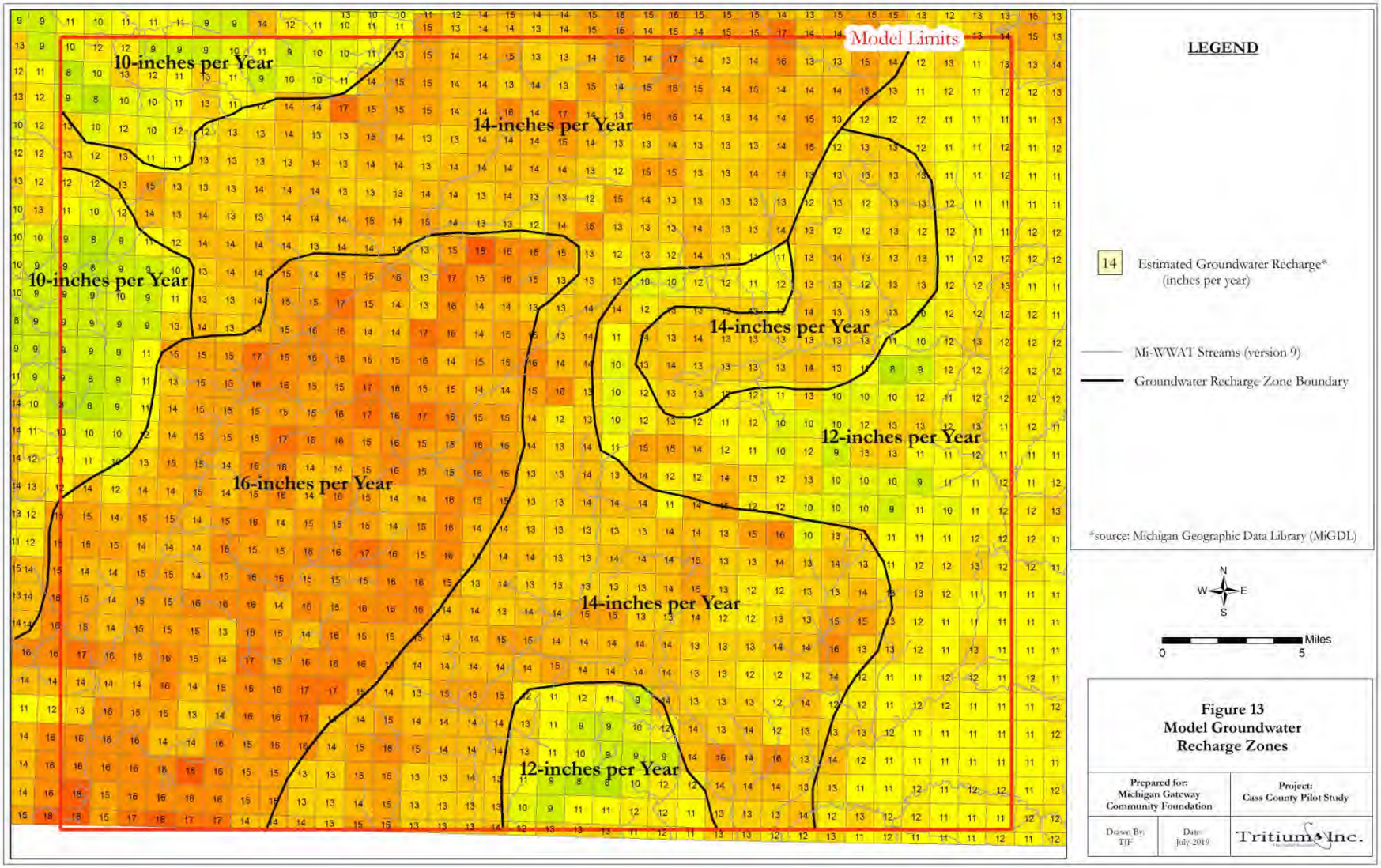

NORTHEAST
C
SOUTHWEST
C'
Elev. ft (amsl)
EE'
BB'
FF'
GG'
Diamond Lake
Potential Aquifer
Aquitard
Well ID
Static Water Level
Casing
Screen
Horizontal Scale
0
4 Miles
Static Water Level
Upper and Lower Boundaries of Aquitard Package
Horizontal Scale
1 : 168,960
1 inch = 14,080 feet
Vertical Scale
1 inch = 40 feet
Vertical Exaggeration
of 352
Figure CC'
Geological Cross-Section
Project:
CCAPP
Drawn By:
STM
Date:
January 2019
Prepared for:
SWMFRWU
Tritium Inc.

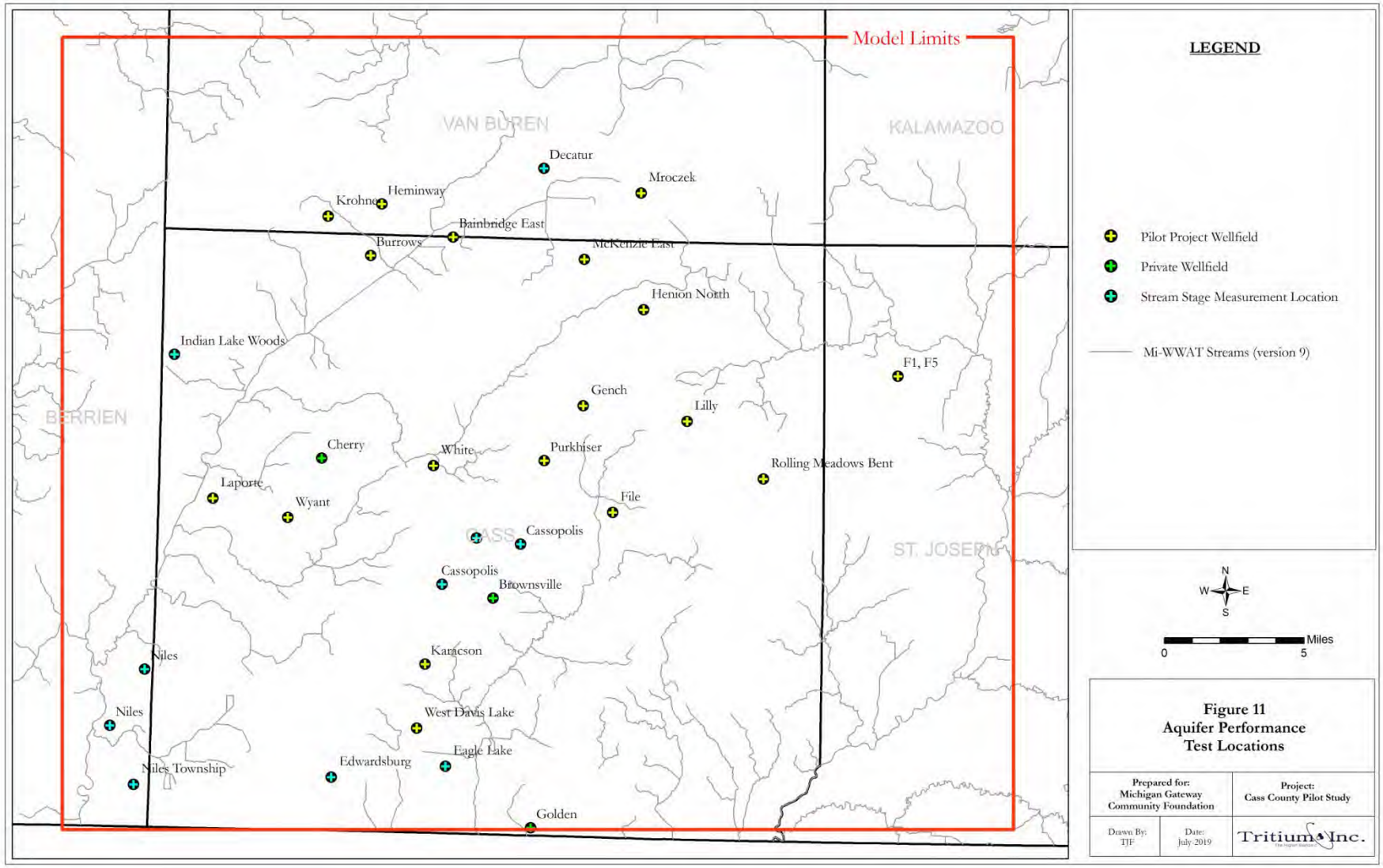


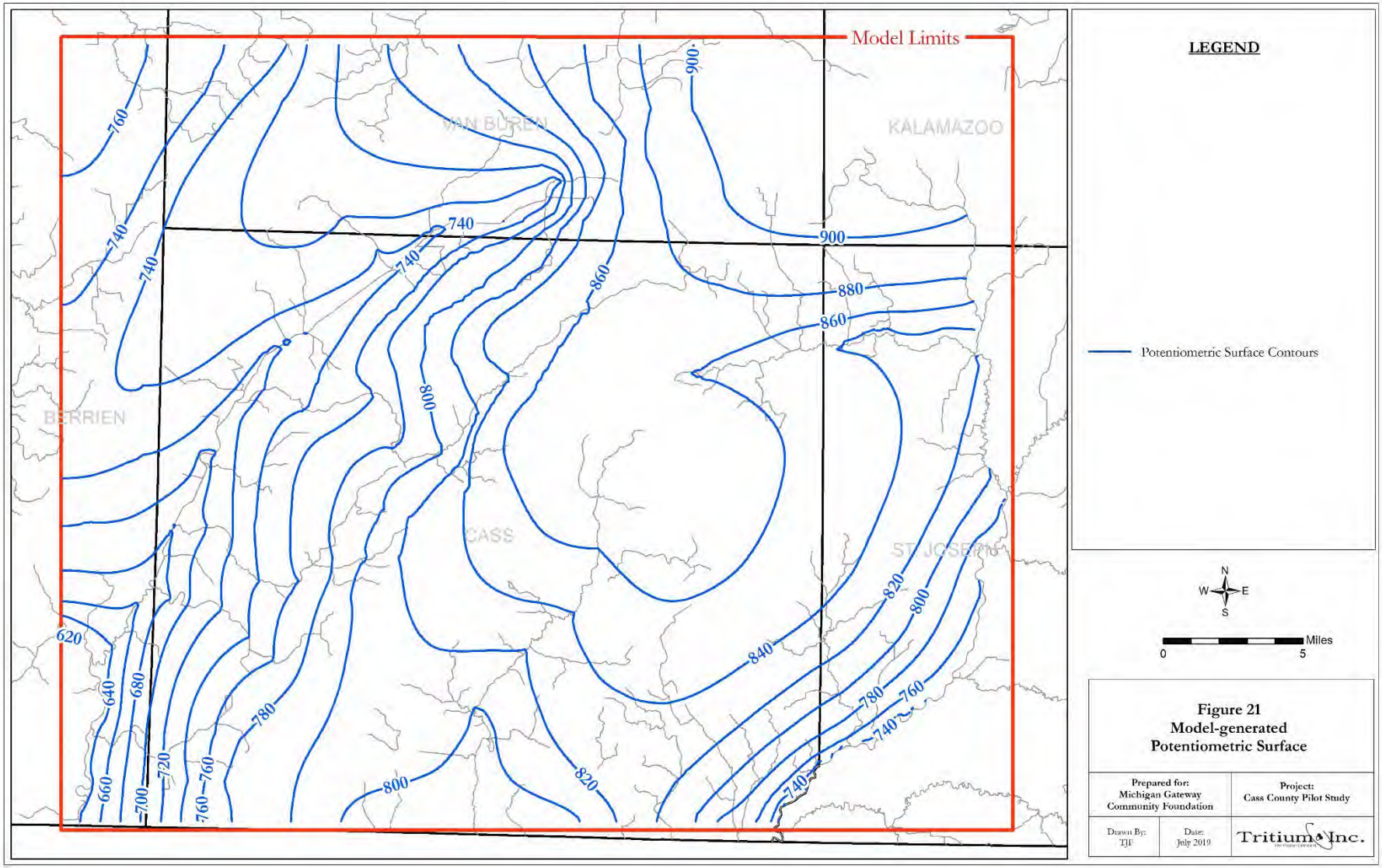
- 5 LAYERS
- 200-FT BY 200-FT CELL GRID
- 3.1 MILLION ACTIVE CELLS



Boundary	Basis
Constant Head	Groundwater Contour
No-Flow	Groundwater Flowline
River	Rivers and Streams


Model Limits
10-inches per Year
14-inches per Year
10-inches per Year
14-inches per Year
12-inches per Year
16-inches per Year
14-inches per Year
12-inches per Year
LEGEND
14 Estimated Groundwater Recharge* (inches per year)
Mi-WWAT Streams (version 9)
Groundwater Recharge Zone Boundary
*source: Michigan Geographic Data Library (MiGDL)
N
W
E
S
Miles
0
5
Figure 13
Model Groundwater Recharge Zones
Prepared for: Michigan Gateway Community Foundation
Project: Cass County Pilot Study
Drawn By: TJF
Date: July 2019
Tritium Inc.

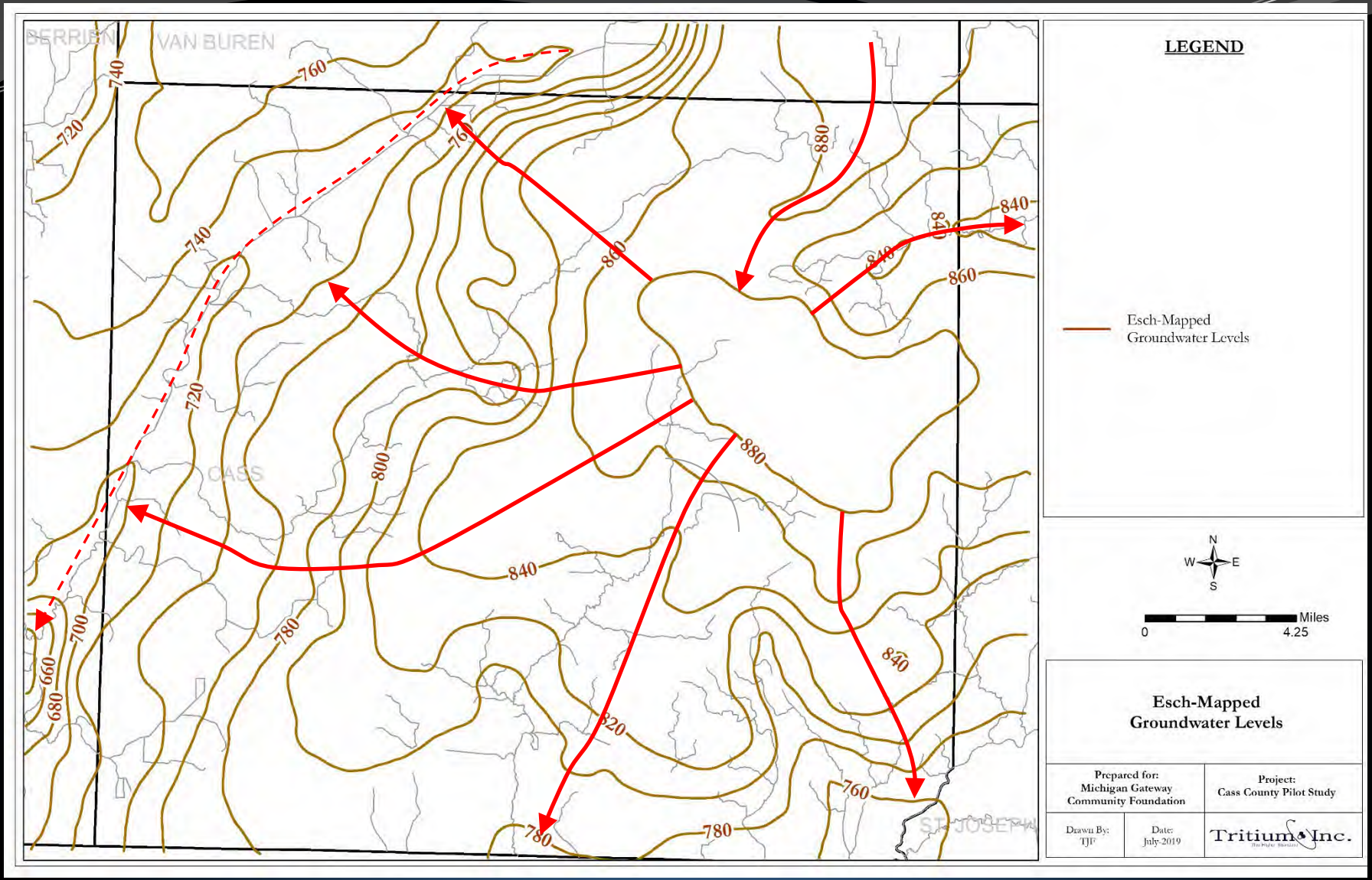

Model Limits
VAN BUREN
KALAMAZOO
BERRIEN
CASS
ST. JOSEPH
Decatur
Mroczek
Heminway
Krohne
Bainbridge East
Burrows
McKenzie East
Henion North
Indian Lake Woods
F1, F5
Gench
Lilly
Cherry
White
Purkhiser
Rolling Meadows Bent
Laporte
Wyant
File
Cassopolis
Cassopolis
Brownsville
Niles
Karacson
Niles
West Davis Lake
Eagle Lake
Niles Township
Edwardsburg
Golden
LEGEND
Pilot Project Wellfield
Private Wellfield
Stream Stage Measurement Location
Mi-WWAT Streams (version 9)
N
W
E
S
Miles
0
5
Figure 11
Aquifer Performance
Test Locations
Prepared for:
Michigan Gateway
Community Foundation
Project:
Cass County Pilot Study
Drawn By:
TJF
Date:
July 2019
Tritium Inc.



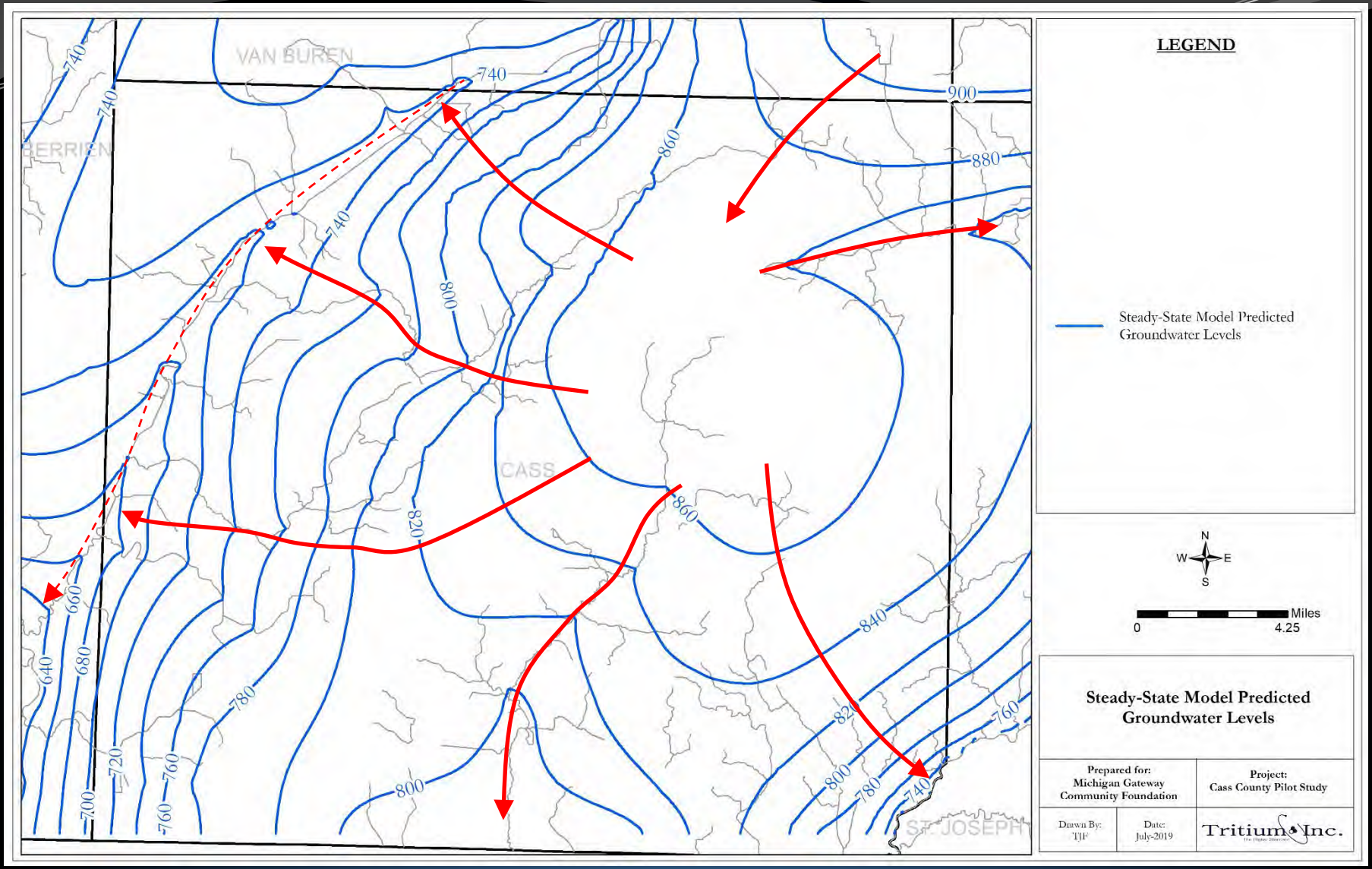
MODEL-PREDICTED GROUNDWATER LEVELS IN LAYER 1

STEADY-STATE CALIBRATION

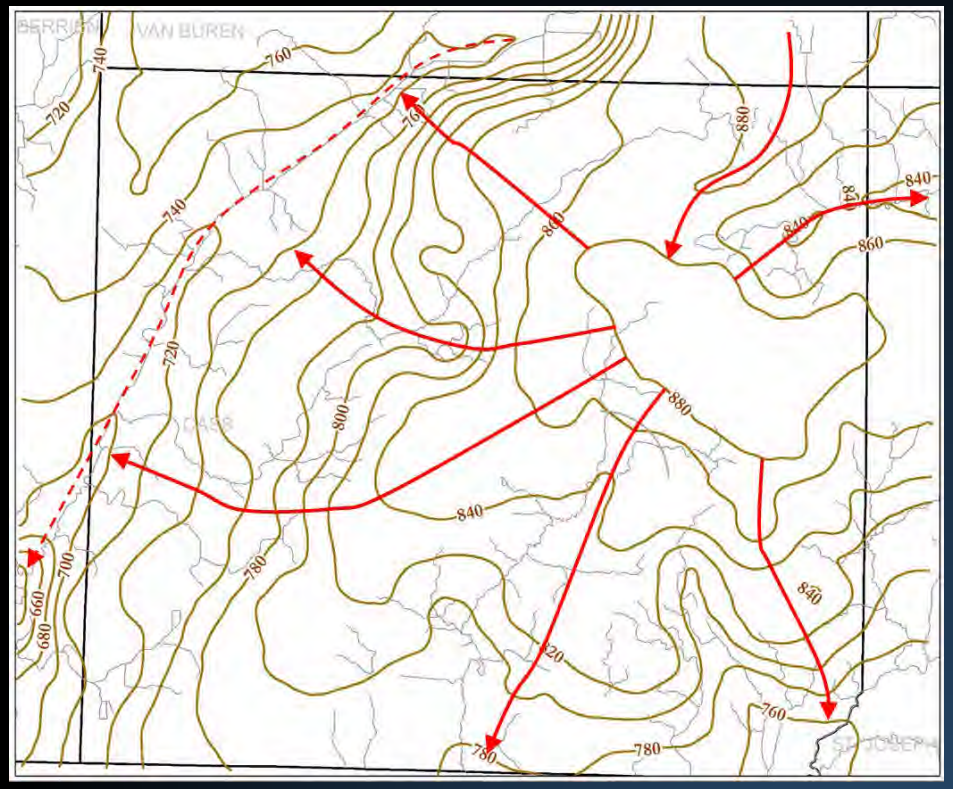
1. GRAPHICAL COMPARISON
2. CALIBRATION TARGETS
   - RESIDUAL DISTRIBUTION
   - RESIDUAL PLOTS
   - STATISTICAL ANALYSIS



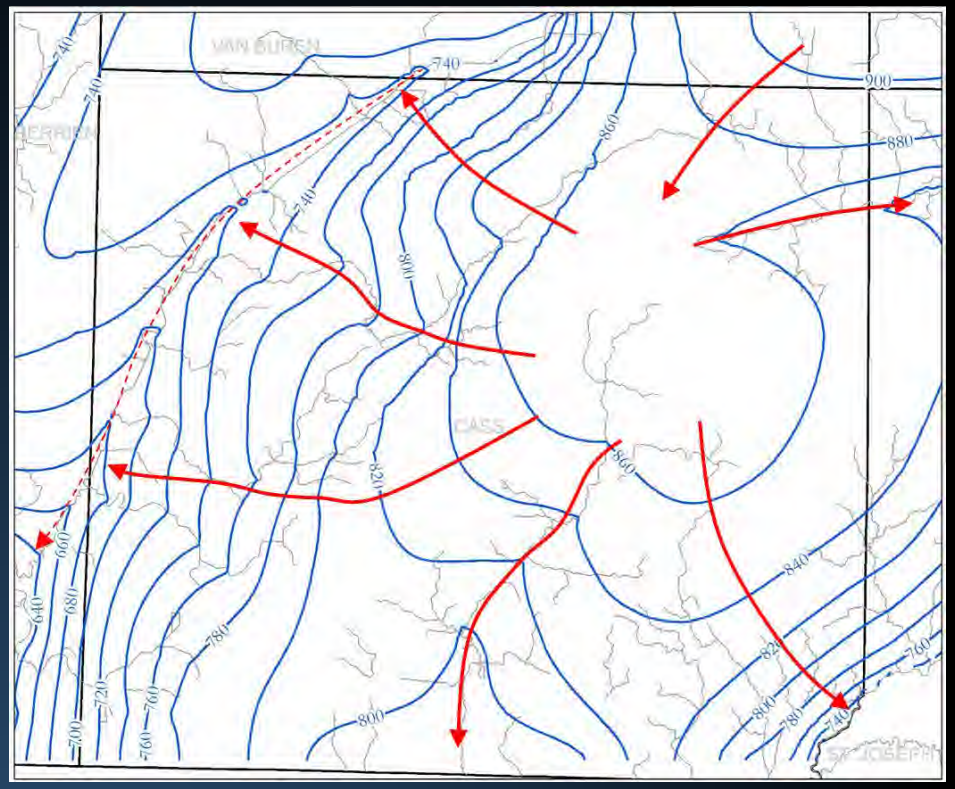
GROUNDWATER LEVELS GENERATED FROM WELLOGIC DATABASE (ESCH)



MODEL-PREDICTED GROUNDWATER LEVELS IN LAYER 1



ESCH WELLOGIC WATER LEVELS



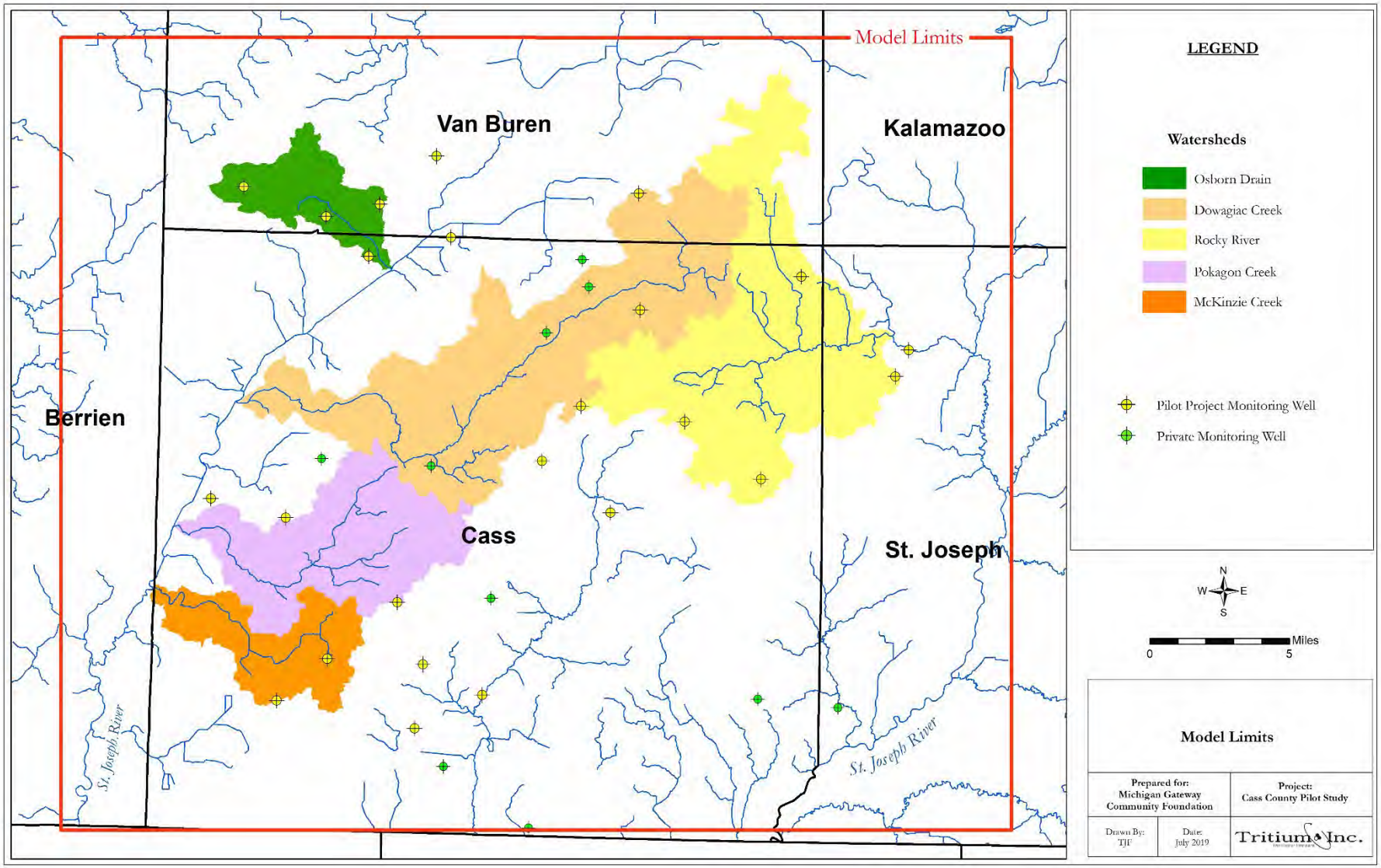
MODEL-PREDICTED WATER LEVELS

CALIBRATION TARGETS

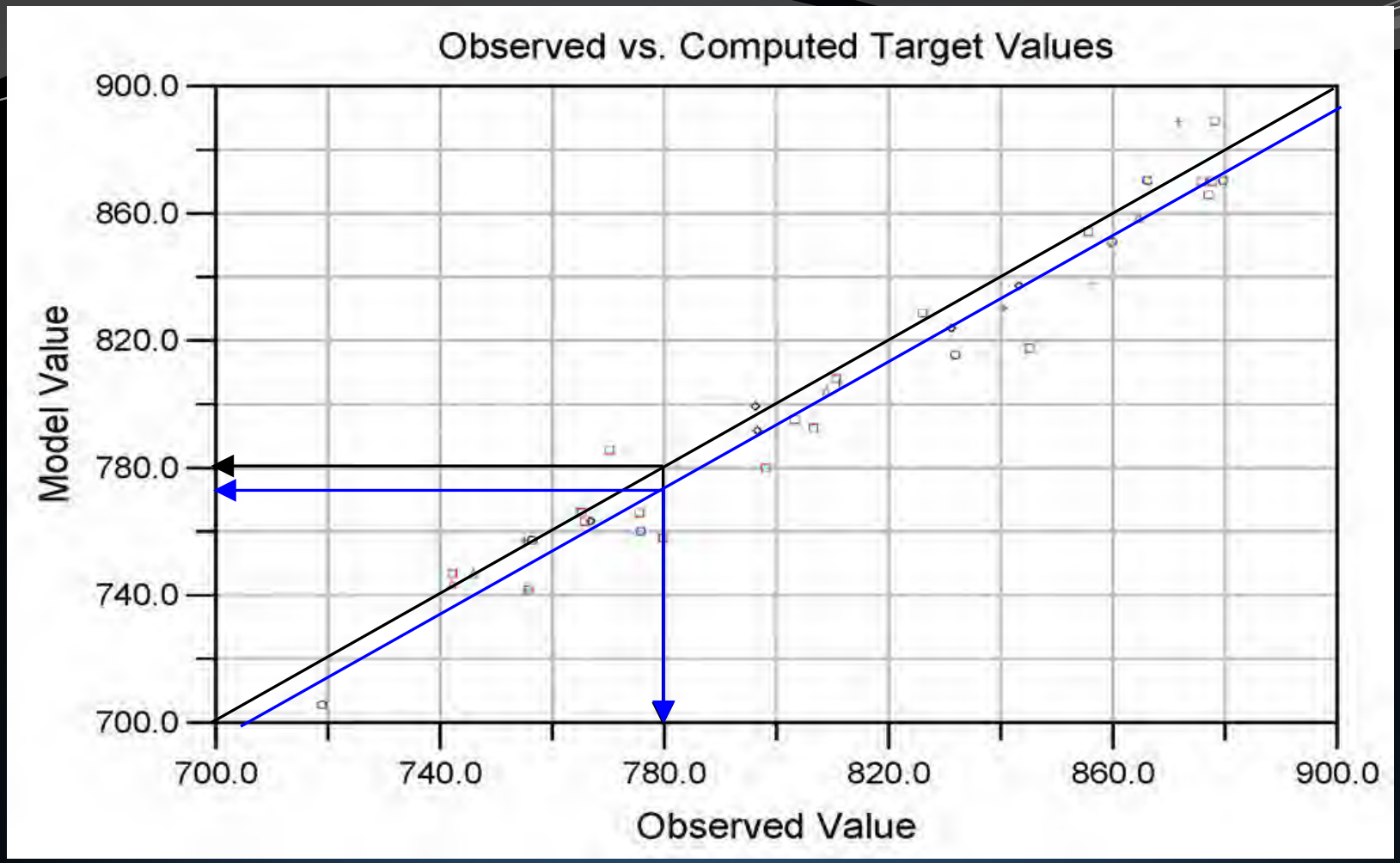
THREE SETS OF DATA

CALIBRATION SET #1

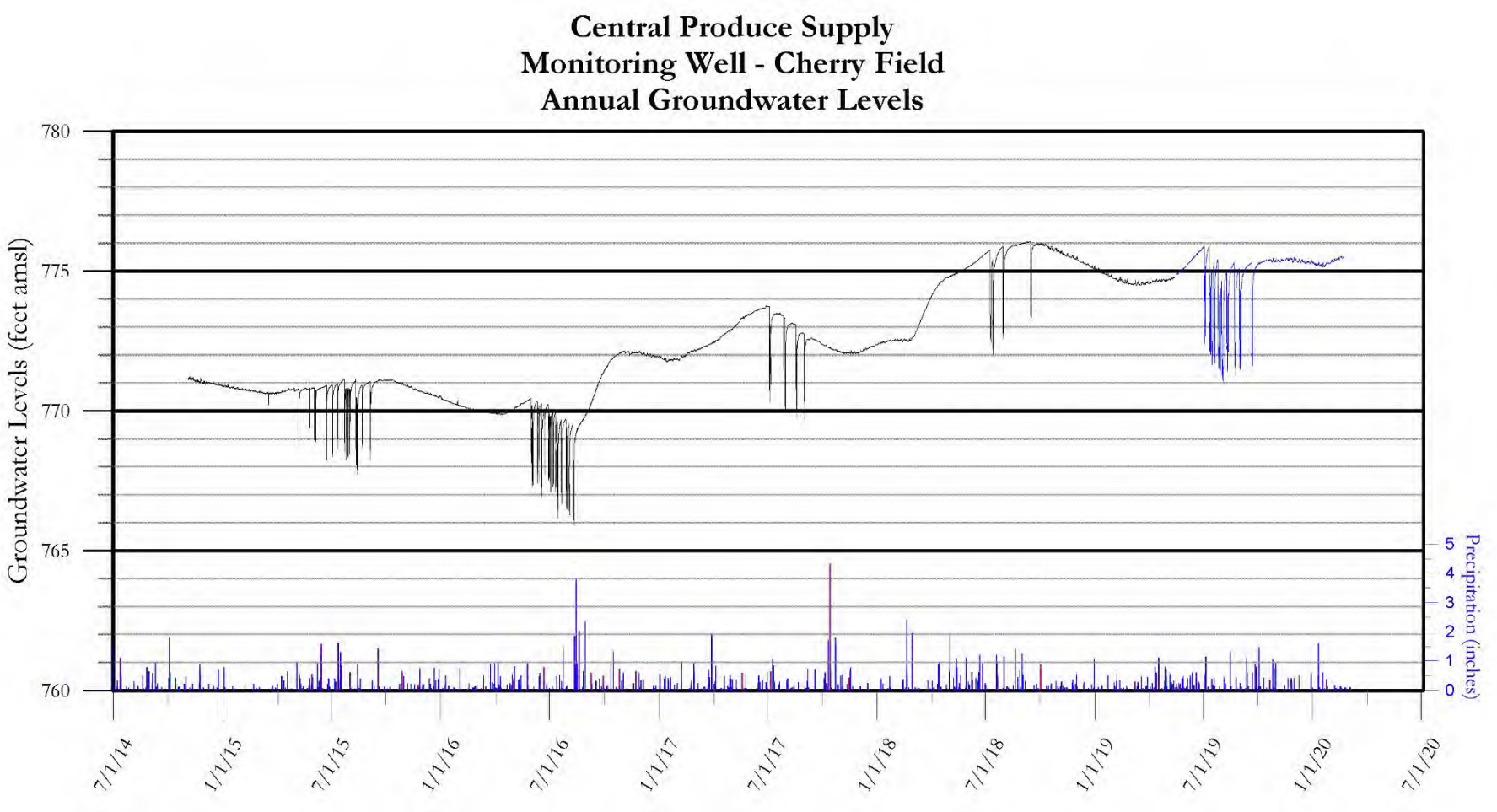
MONITORING WELLS



MONITORING WELL CALIBRATION TARGETS



STEADY-STATE HEAD CALIBRATION MODEL VERSUS MONITORING WELLS


Central Produce Supply
Monitoring Well - Cherry Field
Annual Groundwater Levels
Groundwater Levels (feet amsl)
780
775
770
765
760
Precipitation (inches)
5
4
3
2
1
0
7/1/14
1/1/15
7/1/15
1/1/16
7/1/16
1/1/17
7/1/17
1/1/18
7/1/18
1/1/19
7/1/19
1/1/20
7/1/20

STATISTICAL EVALUATION
MONITORING WELL MEASUREMENTS

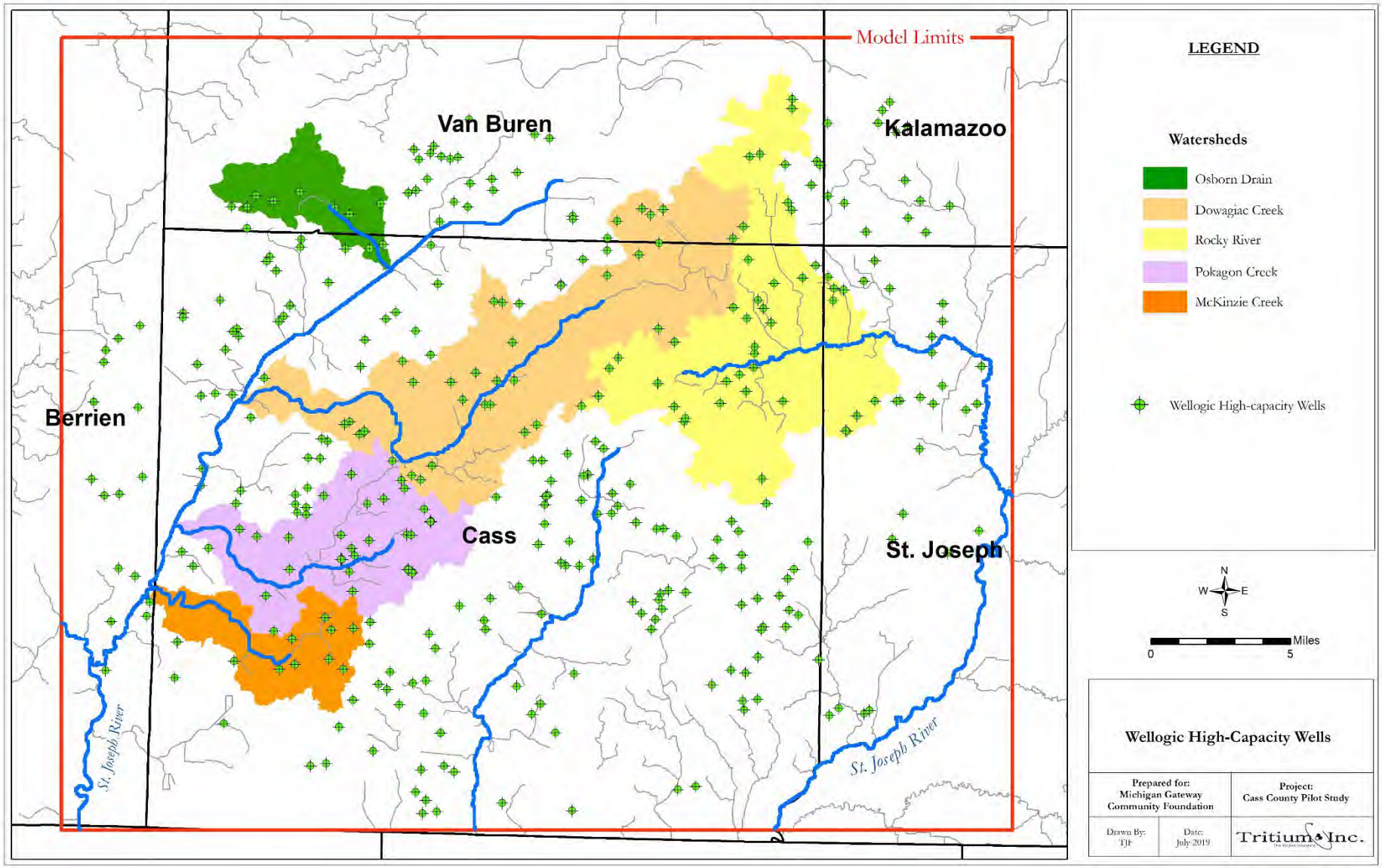
Residual Mean	5.67
Absolute Residual Mean	8.72
Residual Std. Deviation	9.24
Min. Residual	-17.09
Max. Residual	27.38
Number of Observations	42
Range in Observations	161
R-squared	0.961
Percent Model Error	3.89%
Global Mass Balance Error	-0.0046%

Target is <10% of this value

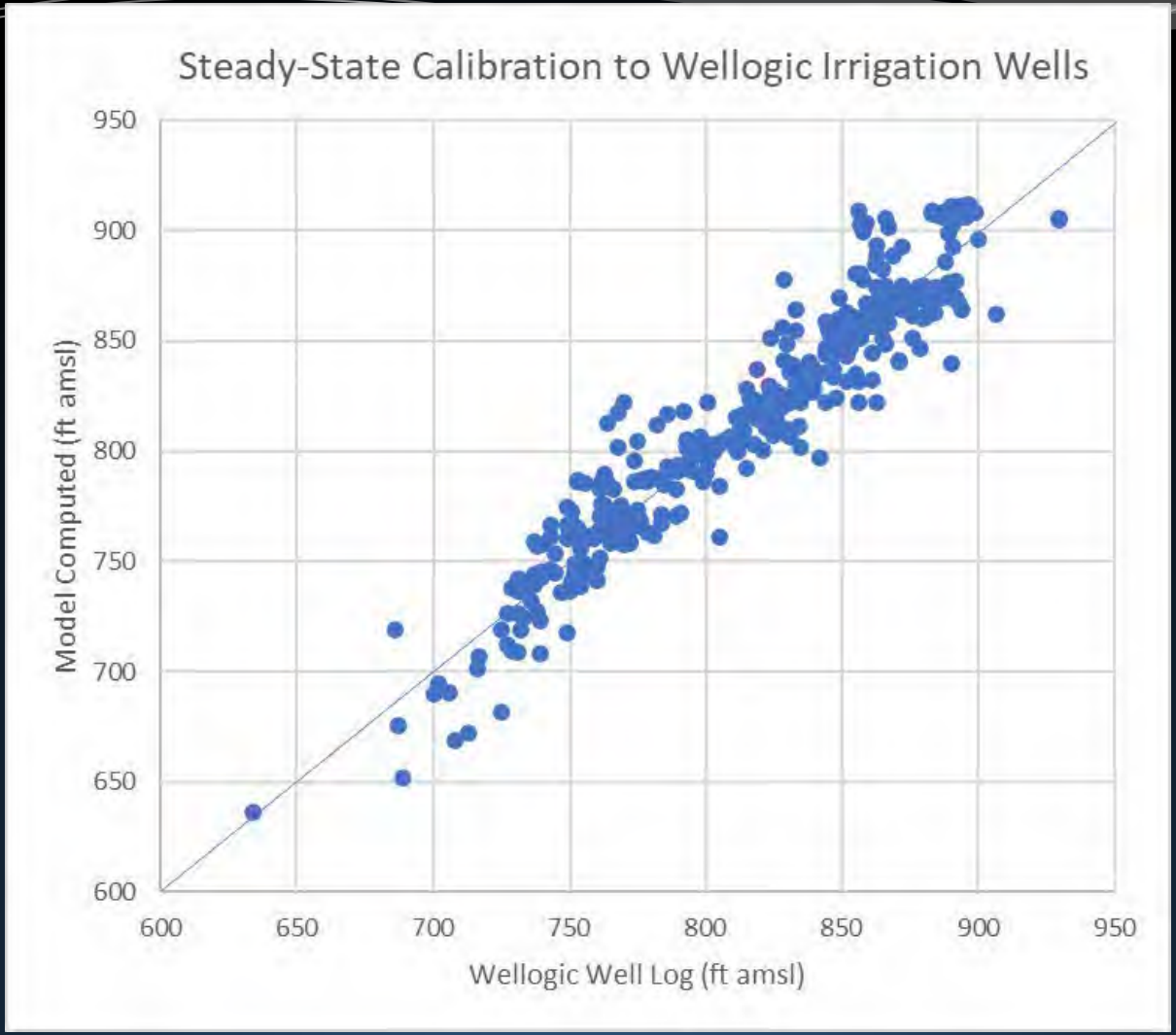
Target is +/- 0.05%

CALIBRATION SET #2

WELLOGIC
HIGH-CAPACITY WELLS
LOG DATA



WELLOGIC HIGH-CAPACITY WELL TARGETS



STEADY-STATE HEAD CALIBRATION
MODEL VERSUS WELLOGIC WELL LOG VALUES

STATISTICAL EVALUATION
WELLOGIC WELL LOG VALUES

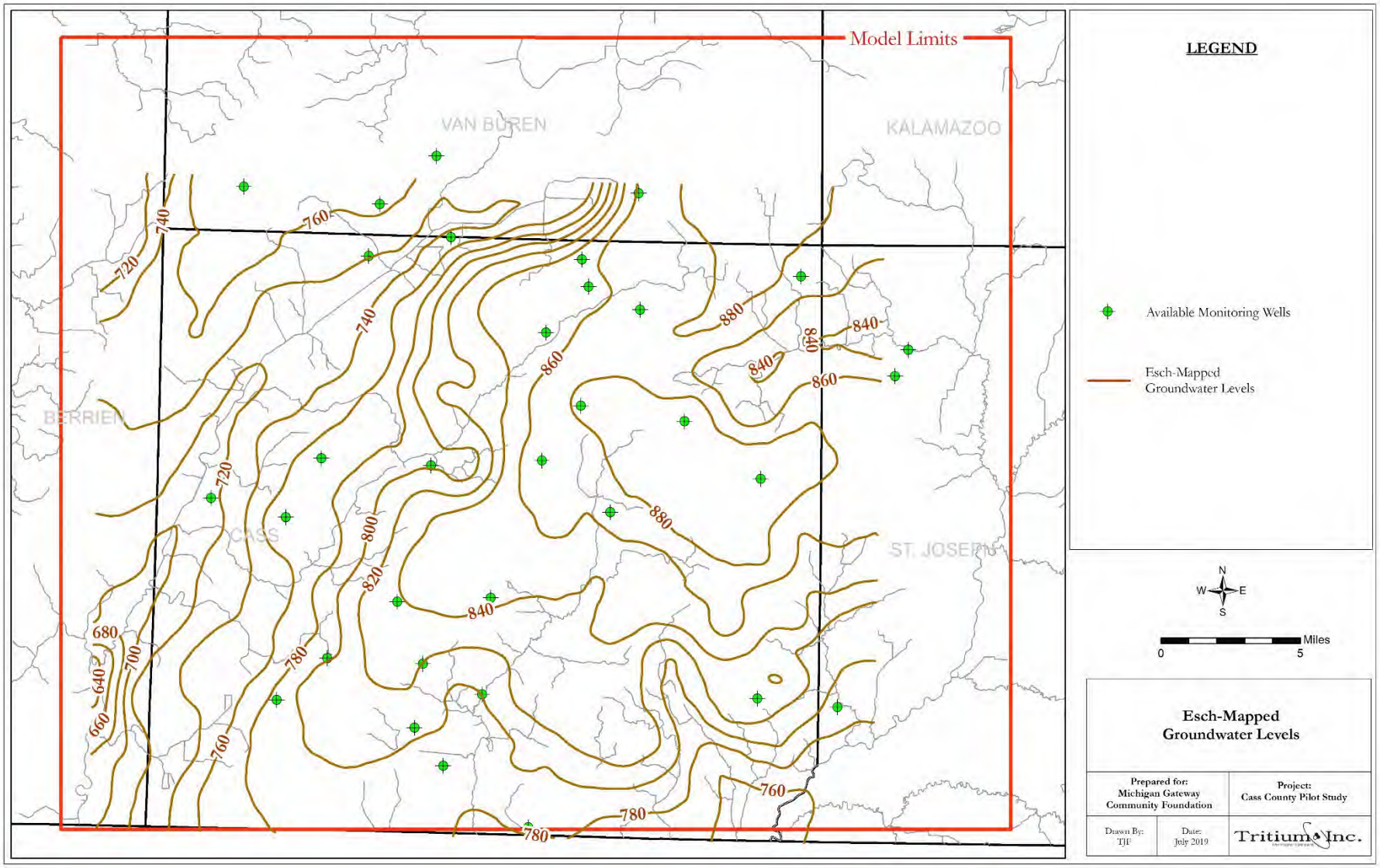
Residual Mean	0.13
Absolute Residual Mean	13.01
Residual Std. Deviation	17.05
Min. Residual	-52.77
Max. Residual	50.56
Number of Observations	370
Range in Observations	296
R-squared	0.961
Percent Model Error	3.89%
Global Mass Balance Error	-0.0046%

Target is <10% of this value

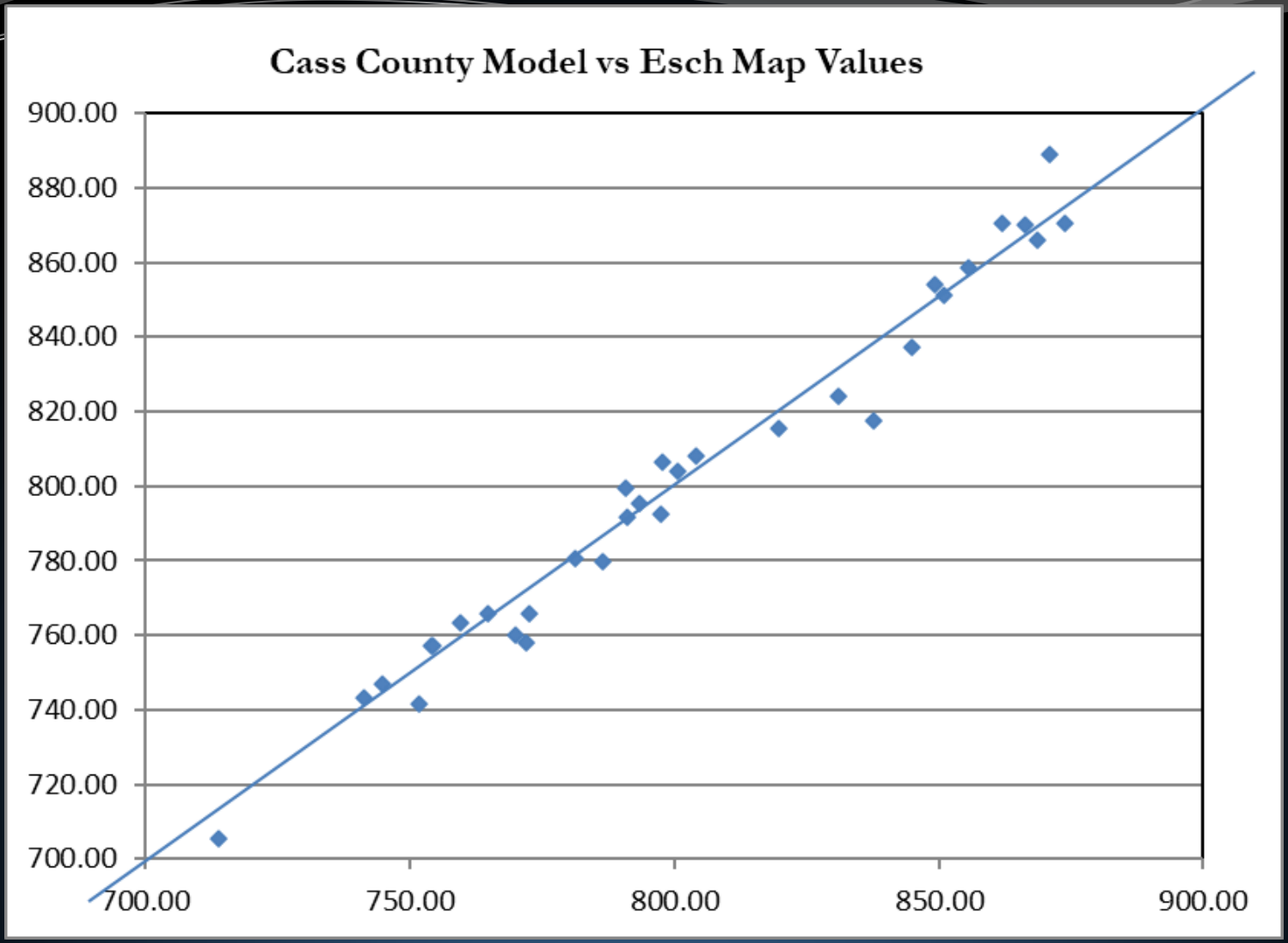
Target is +/- 0.05%

CALIBRATION SET #3

JOHN ESCH
REFINED WELLOGIC DATA



JOHN ESCH REFINED WELLOGIC DATA



STEADY-STATE HEAD CALIBRATION MODEL VERSUS ESCH MAP VALUES

STATISTICAL EVALUATION
ESCH MAP VALUES AT MONITORING WELL LOCATIONS

Residual Mean	0.84
Absolute Residual Mean	5.81
Residual Std. Deviation	7.54
Min. Residual	-17.93
Max. Residual	19.86
Number of Observations	32
Range in Observations	161
R-squared	0.961
Percent Model Error	3.89%
Global Mass Balance Error	-0.0046%

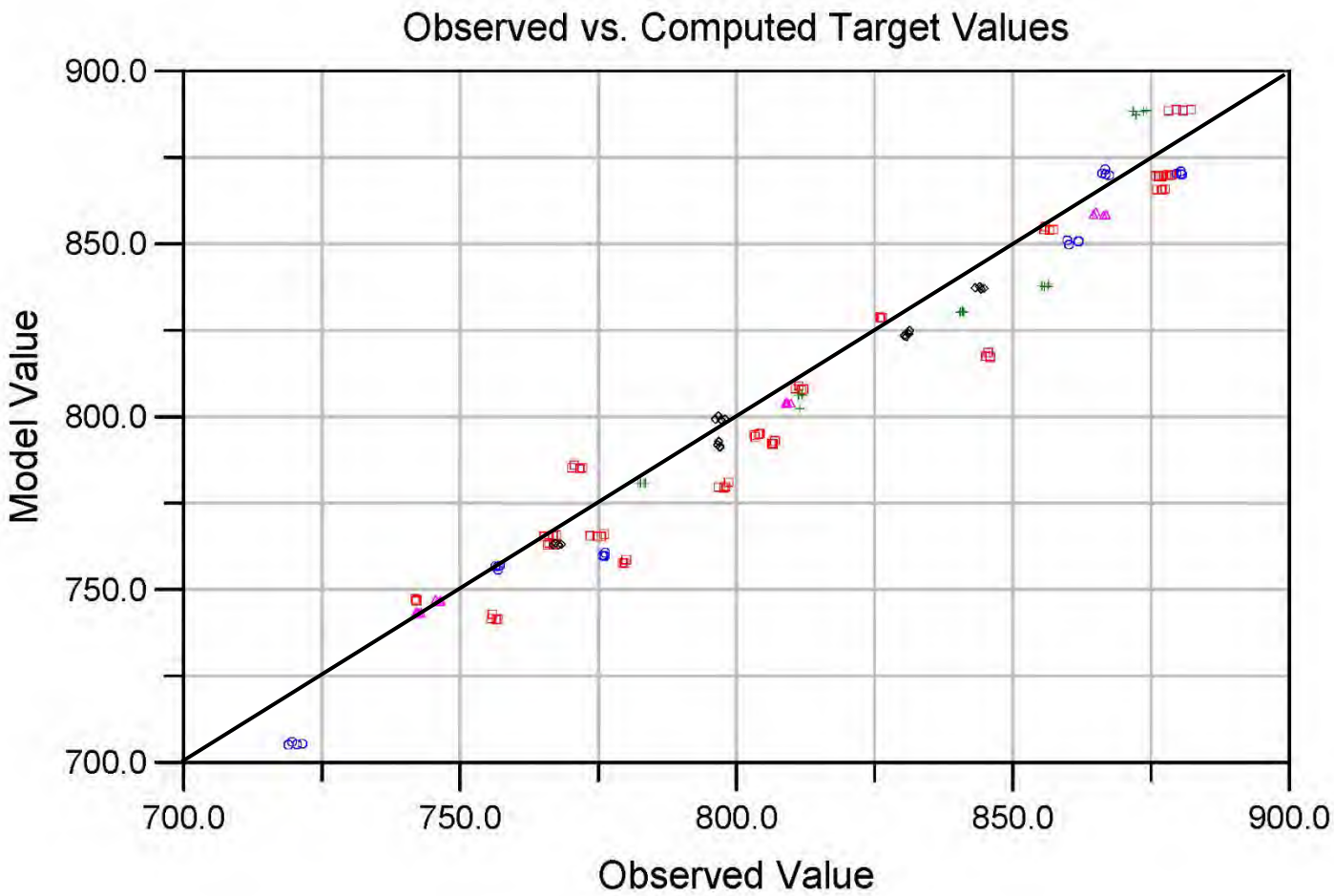
Target is <10% of this value

Target is +/- 0.05%

TRANSIENT CALIBRATION

1. CALIBRATION TARGETS
2. STREAM DISCHARGE
3. STREAMBED FLUX
4. VARIABLE RECHARGE

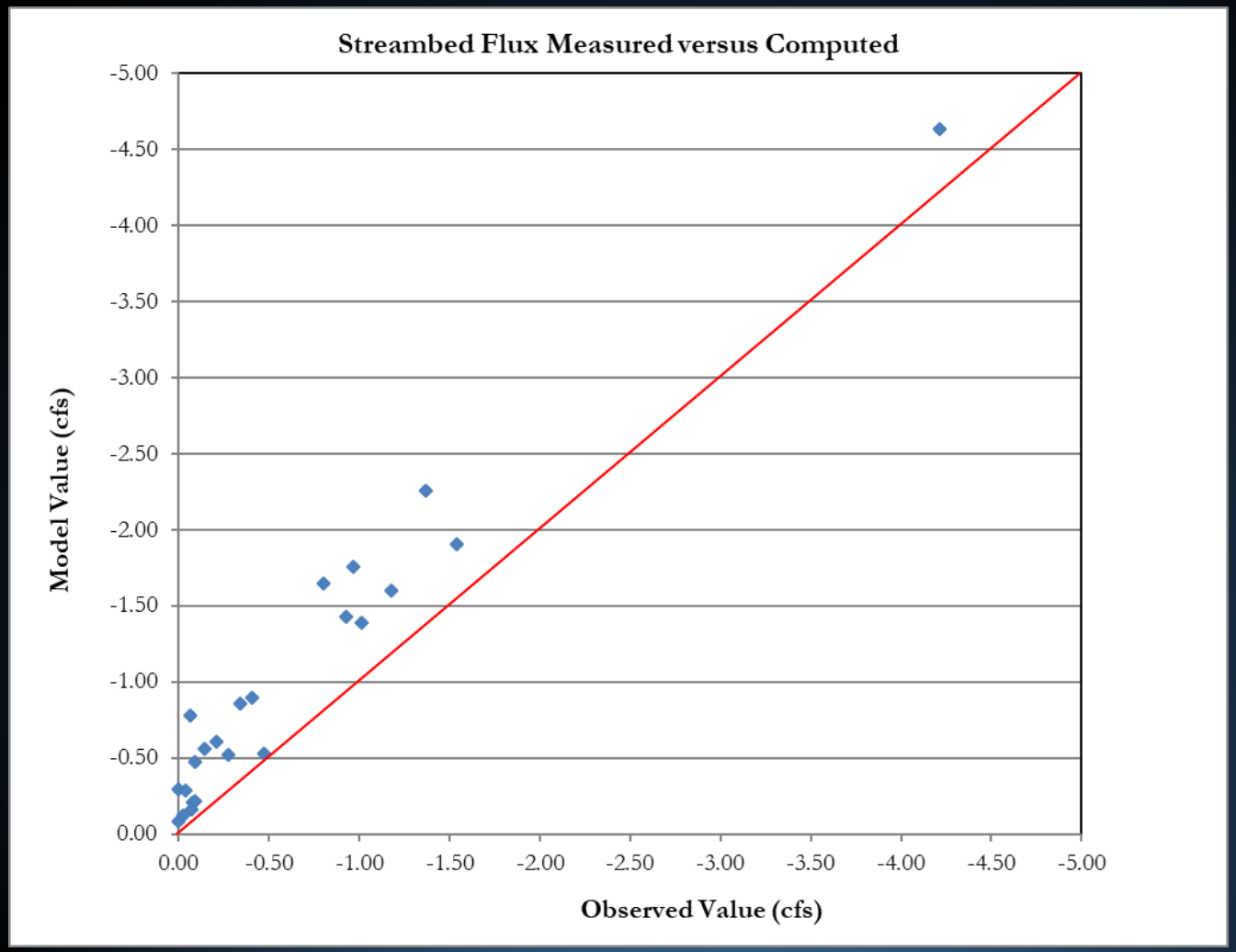
CASS PILOT MODEL
TRANSIENT HEAD CALIBRATION



4 SURVEYS

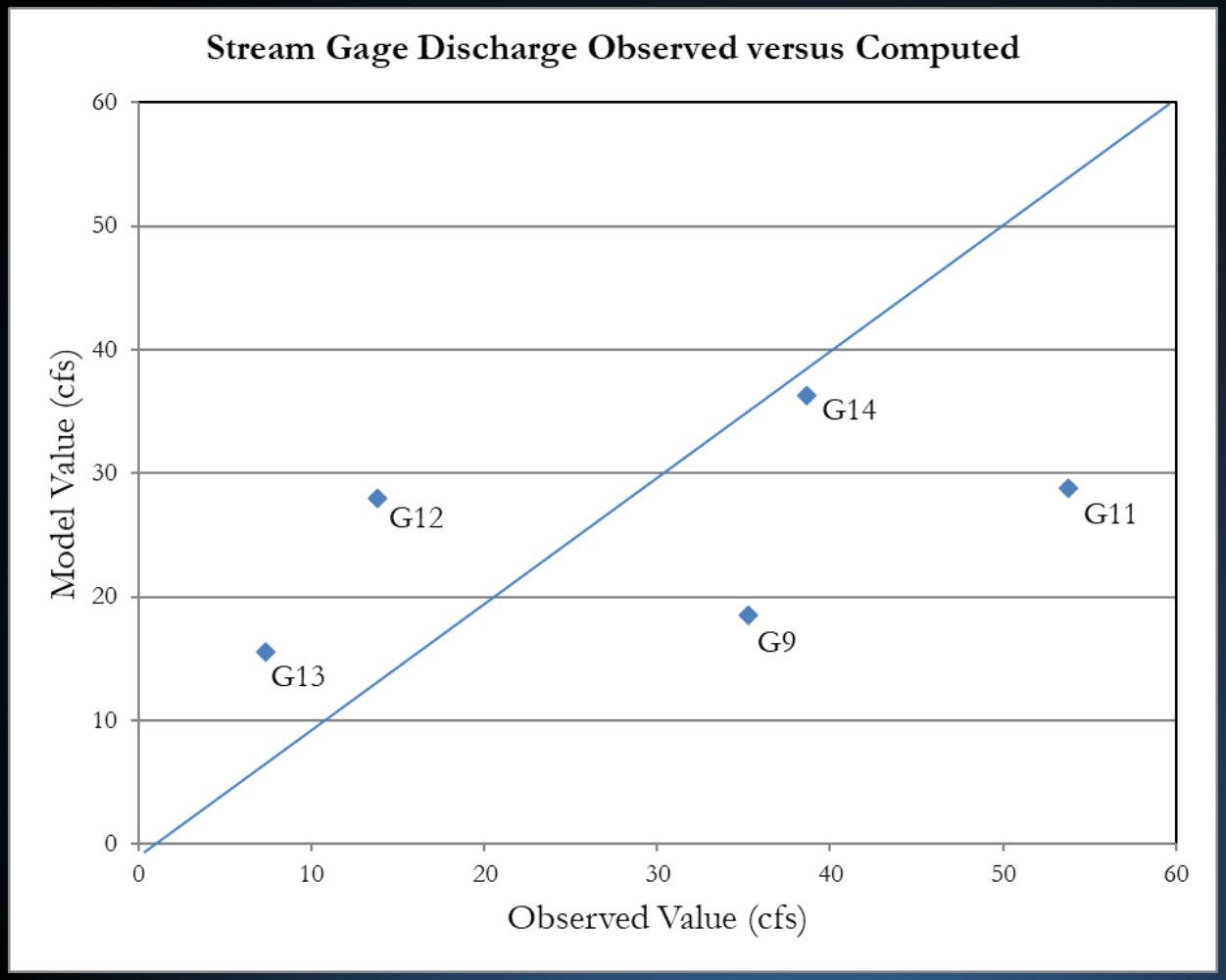
MARCH
MAY
SEPTEMBER
NOVEMBER

STREAMBED FLUX



Computed flux is 1.5x-2x the measured flux

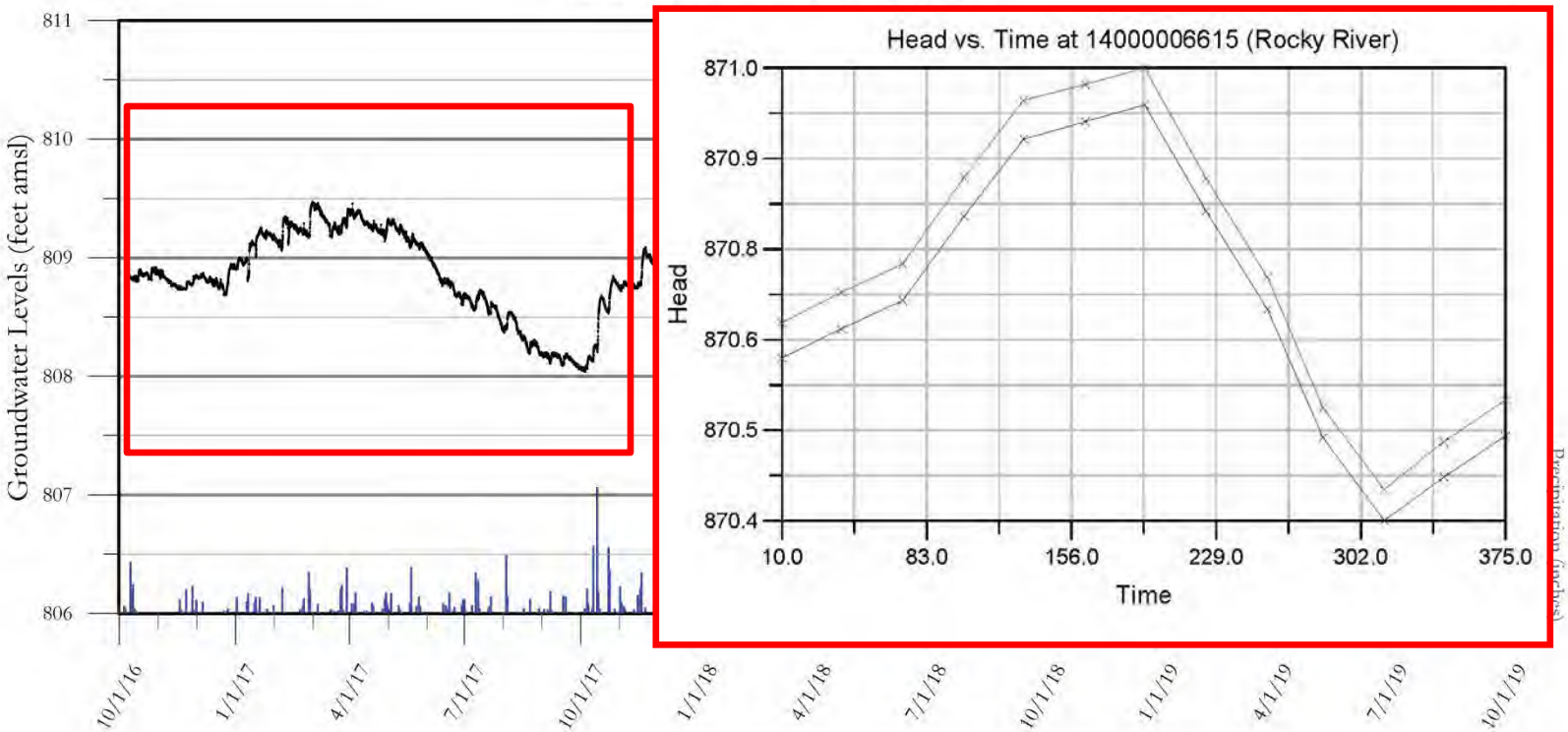
STREAM DISCHARGE



GageNo	Ratio
9	0.52
11	0.54
12	2.03
13	2.13
14	0.94
15	1.53

Minnesota WHP Guidance states the ratio should not exceed 10

Kirkdorfer Farms
Monitoring Well - Nelson
Annual Groundwater Levels



Project: Cass County Assessment Pilot Project

Irrigation Well
Depth: 105 feet
Static: n/a
Screen: 85-105 feet

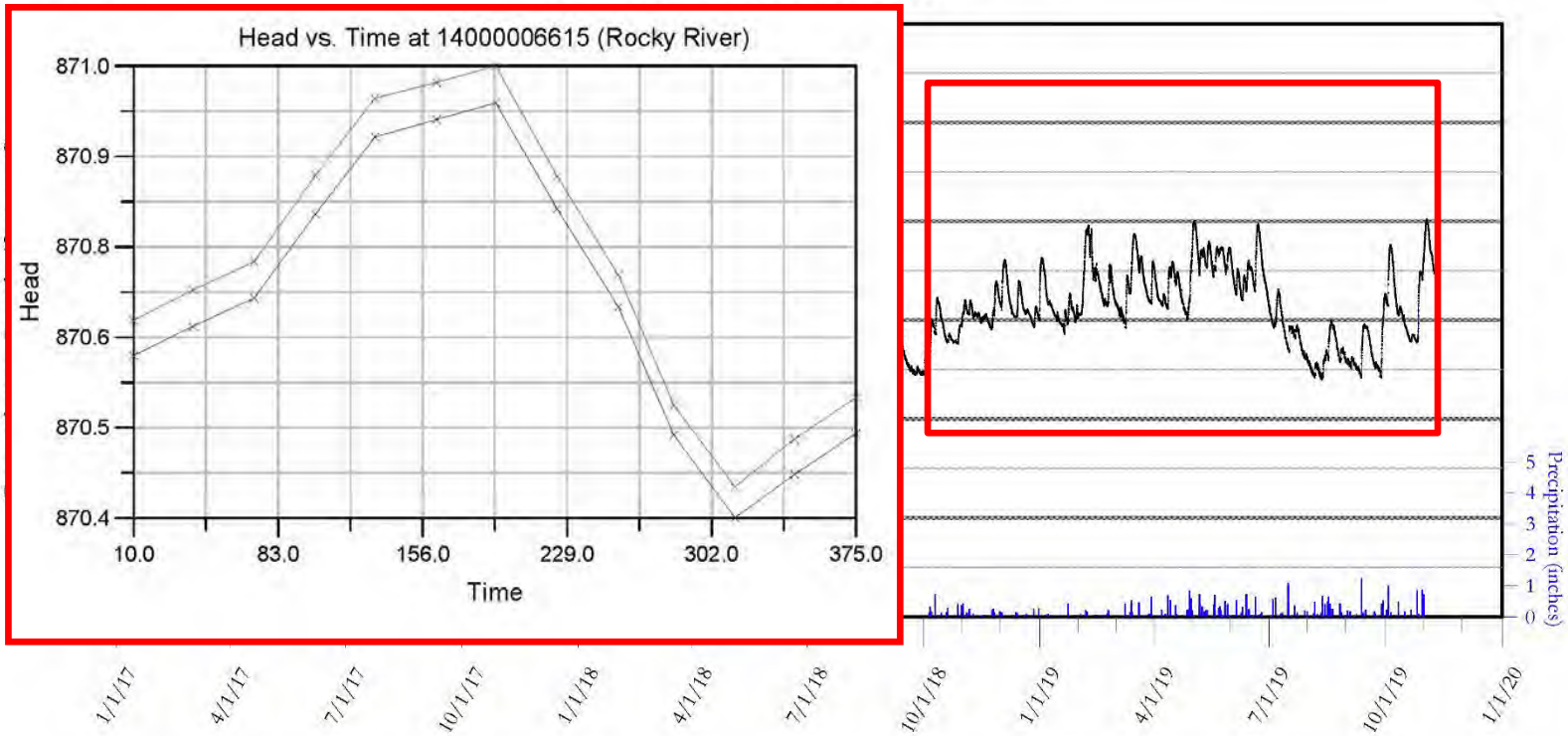
Monitoring Well
Depth: 90 feet
Static: 1.7 feet
Screen: 86-90 feet
Radial Distance: 237 feet

Measured Pumping Rates
Maximum: n/a gpm
Span only: n/a gpm
End Gun: n/a gpm

Weather Station
MAWN Cassopolis

Tritium Inc.
The Higher Standard
1789 E. Bristol Street, Suite B
Elkhart, Indiana 46514
Ph: (574)266-5300
Fax: (574) 266-1795

Dale Bent Farm
Monitoring Well - Farm 2 Field 3 (Shallow)
Annual Groundwater Levels



Project: Cass County Assessment Pilot Project

Irrigation Well
Depth: n/a
Static: n/a
Screen: n/a

Monitoring Well
Depth: 14 feet
Static: 9 feet
Screen: 9-14 feet
Radial Distance: n/a feet

Measured Pumping Rates
Maximum: n/a gpm
Span only: n/a gpm
End Gun: n/a gpm

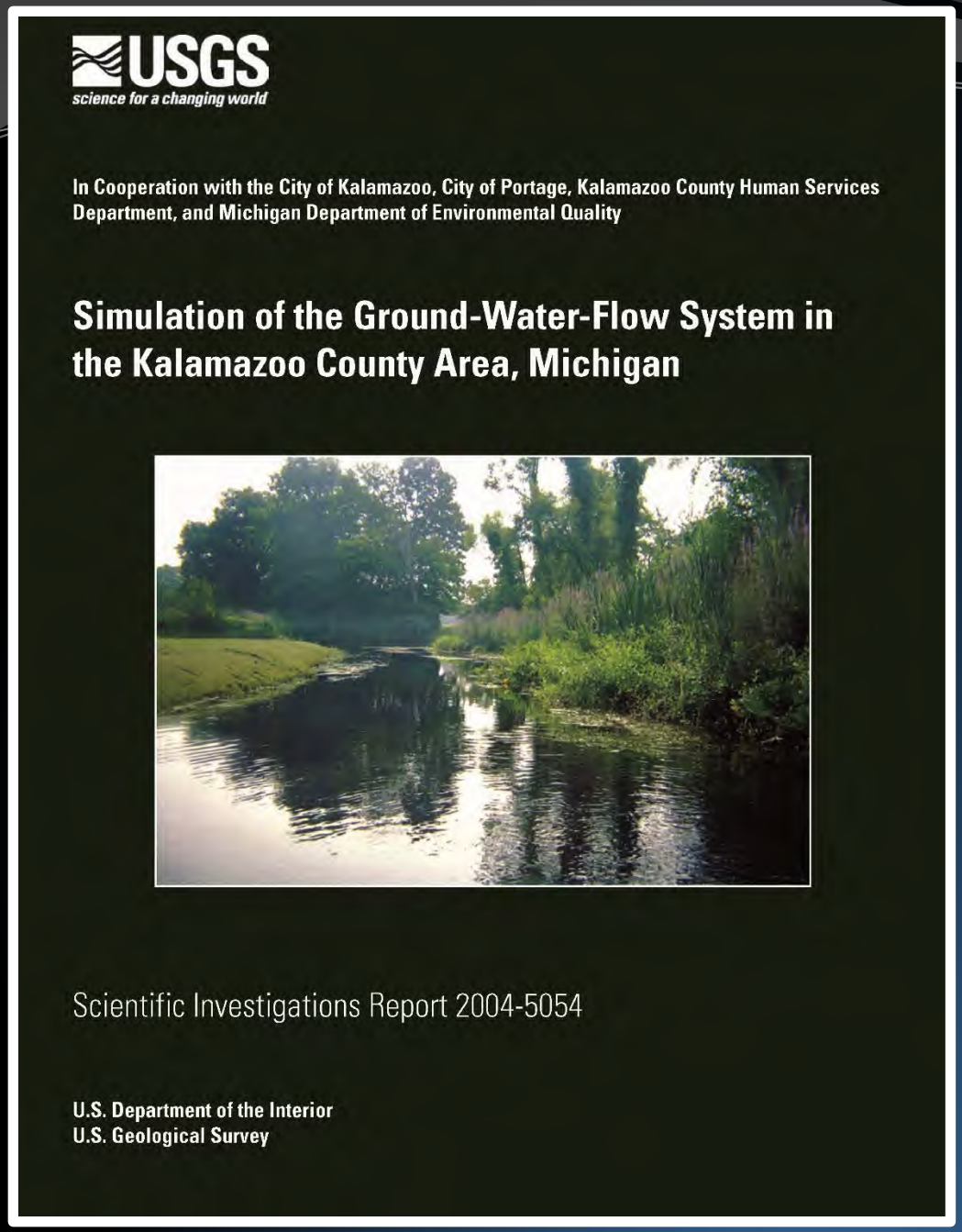
Weather Station
KMISCHOO2
Bent Home Field

Tritium Inc.
The Higher Standard
1789 E. Bristol Street, Suite B
Elkhart, Indiana 46514
Ph: (574)266-5300
Fax: (574) 266-1795

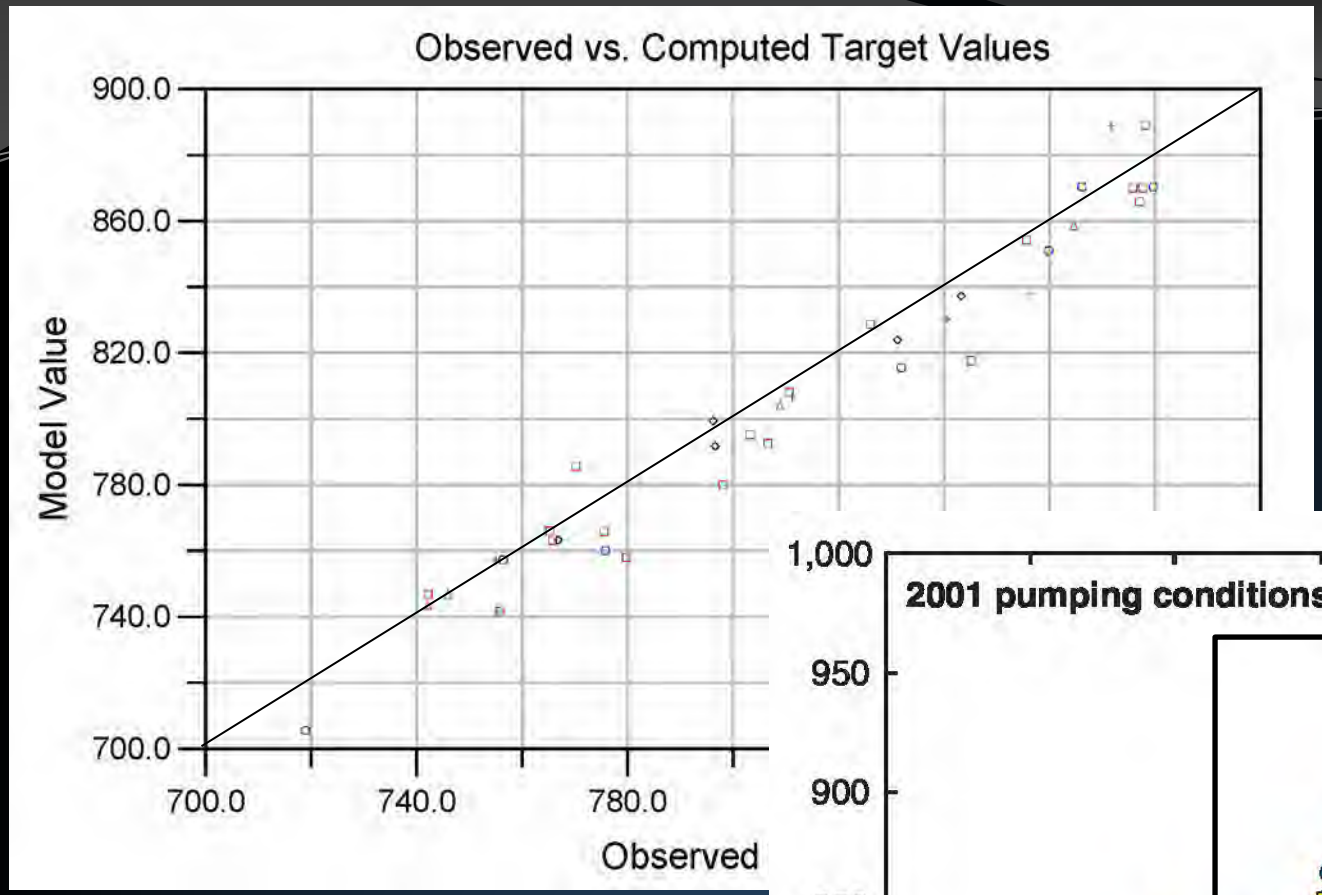
REGIONAL MODELS BY OTHERS

1. Kalamazoo, Michigan
2. LaGrange County, Indiana
3. Milford, Indiana
4. Elkhart, Indiana
5. Berrien County, Michigan
6. Monroe County, Michigan
7. Saginaw County, Michigan
8. Tri-County Area (Lansing), Michigan
9. Cadillac, Michigan

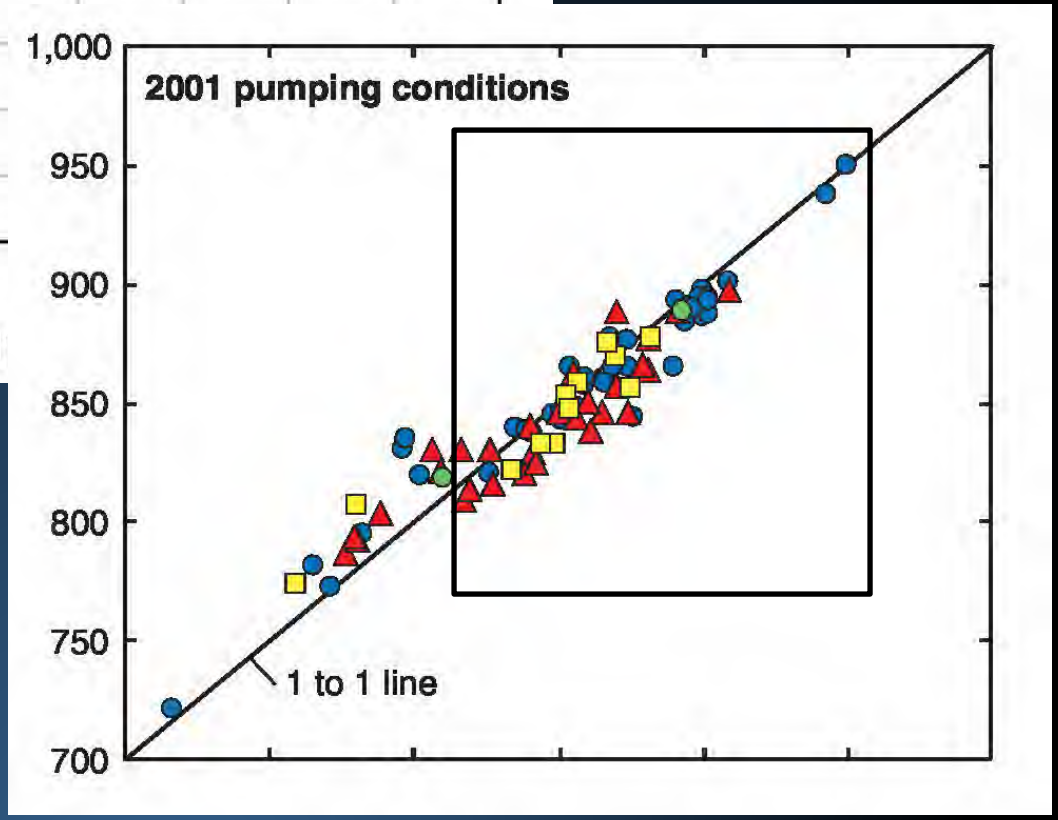
COMPARISON TO KALAMAZOO MODEL



The Kalamazoo County Area model was used to validate the streamflow depletion predictions calculated by the screening tool embedded in the Mi-WWAT



USGS SIR 2004-5054
Kalamazoo County Area



STEADY-STATE HEAD CALIBRATION COMPARISON

USGS SIR 2004-5054

Kalamazoo County Area

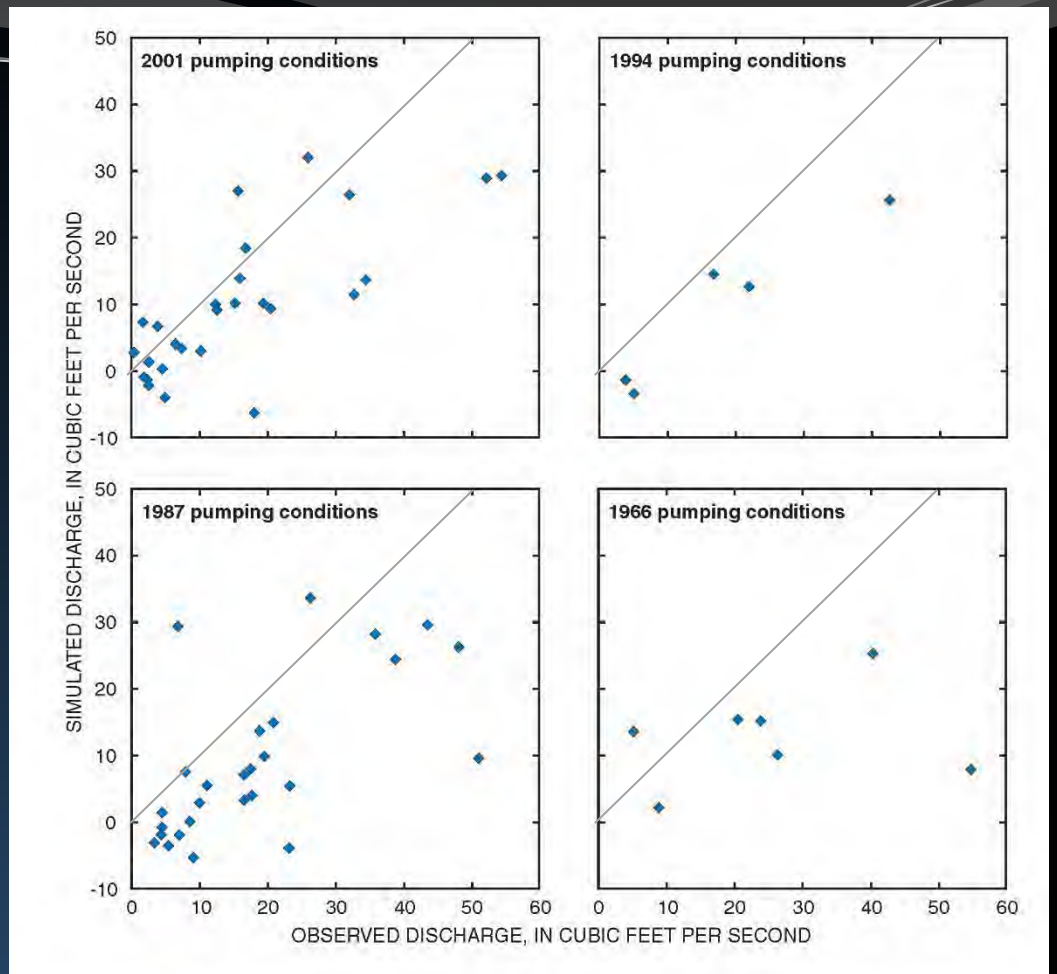
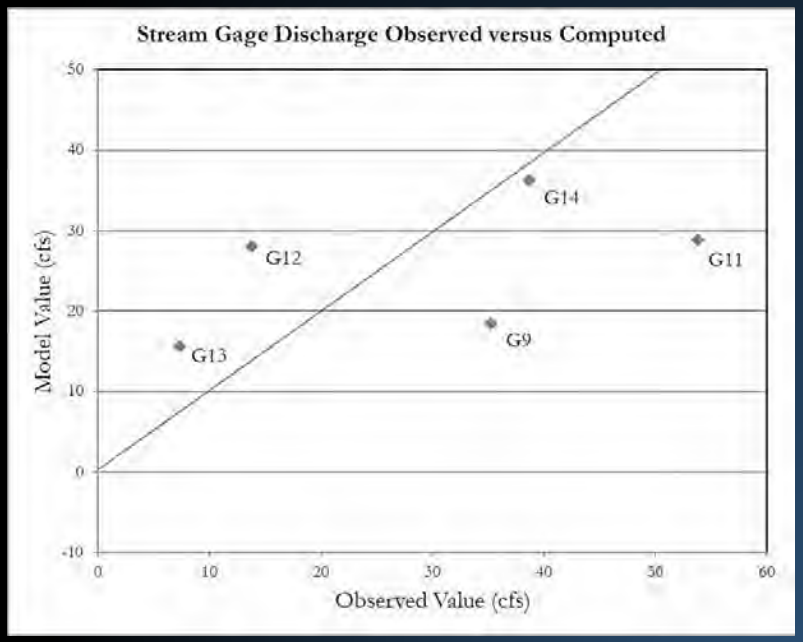


Figure 23. Observed and simulated streamflow for 2001, 1994, 1987, and 1966 pumping conditions, Kalamazoo County area, Michigan.

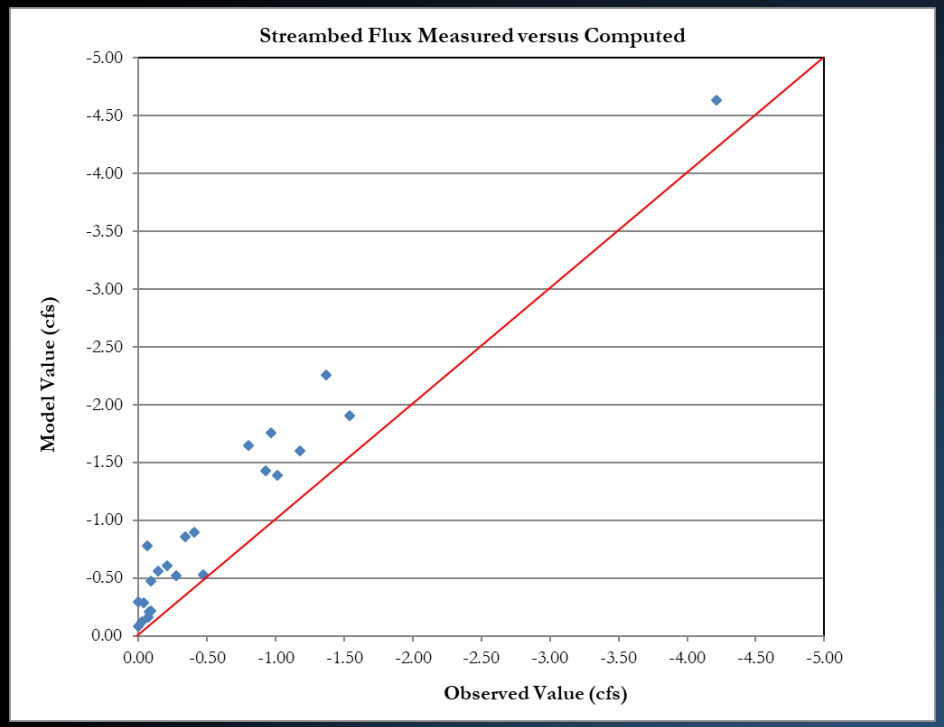
Cass County Pilot



STREAM DISCHARGE TRANSIENT CALIBRATION COMPARISON

USGS SIR 2004-5054
Kalamazoo County Area

Cass County Pilot



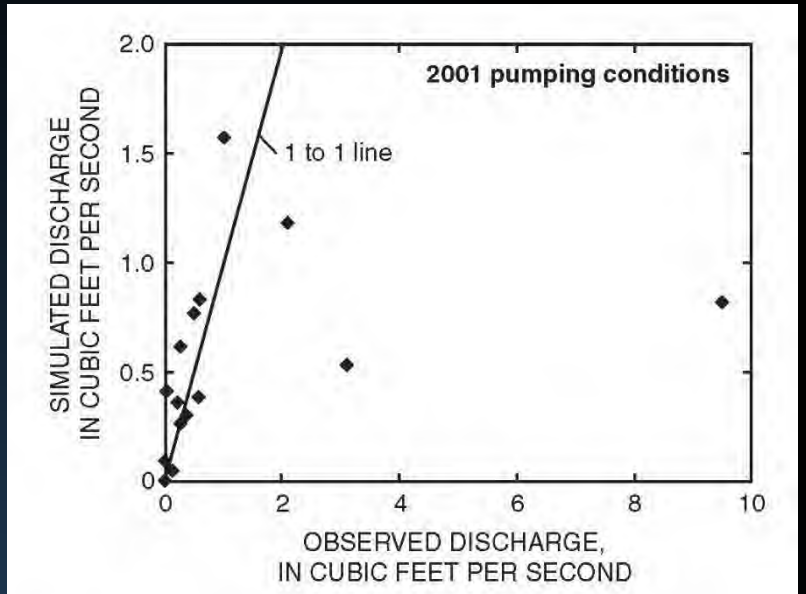


Figure 24. Observed and simulated flow at seepage measurement sites for 2001 pumping conditions, Kalamazoo County area, Michigan.

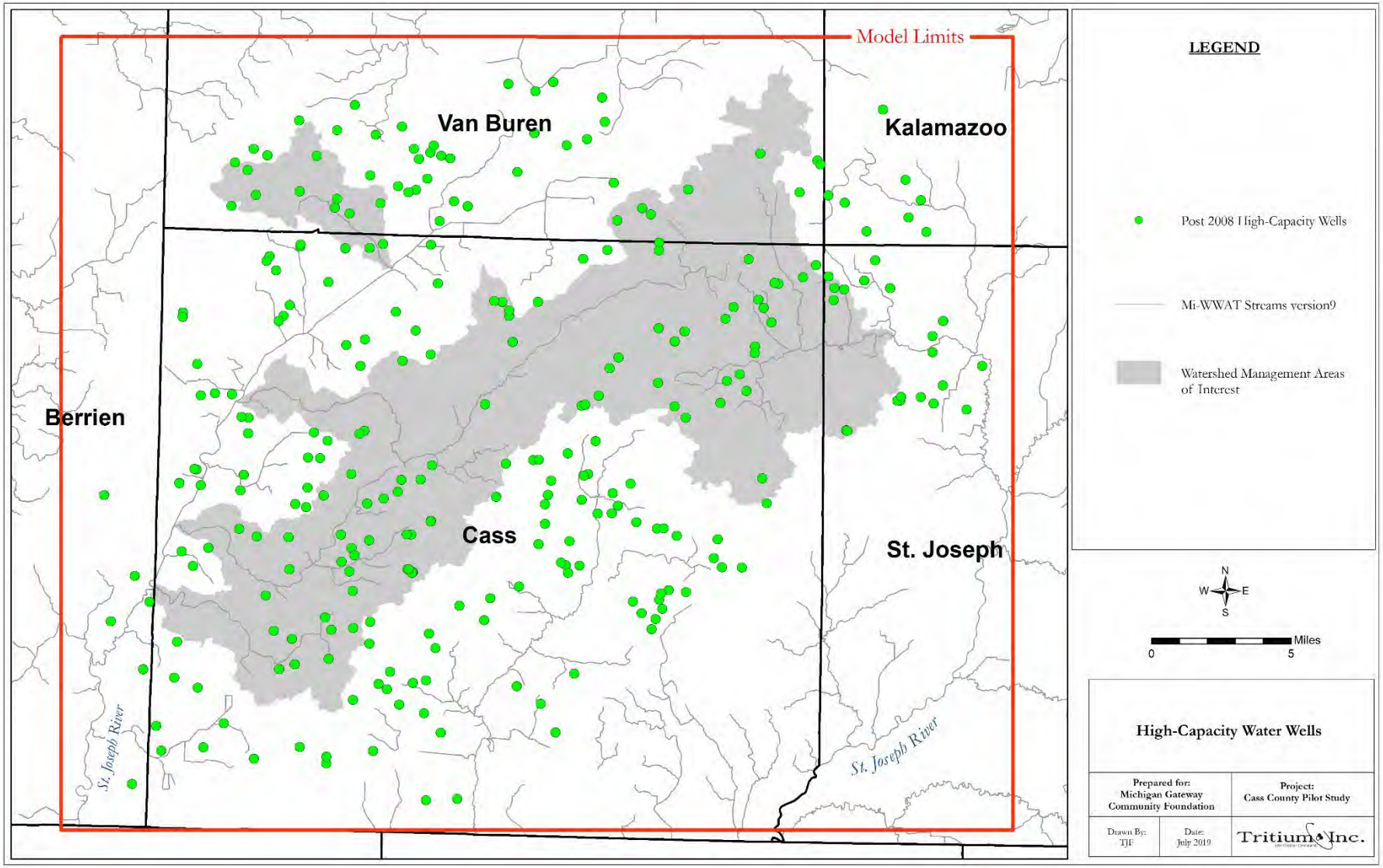
STREAMBED FLUX TRANSIENT CALIBRATION COMPARISON

MODEL CALIBRATION AND VERIFICATION

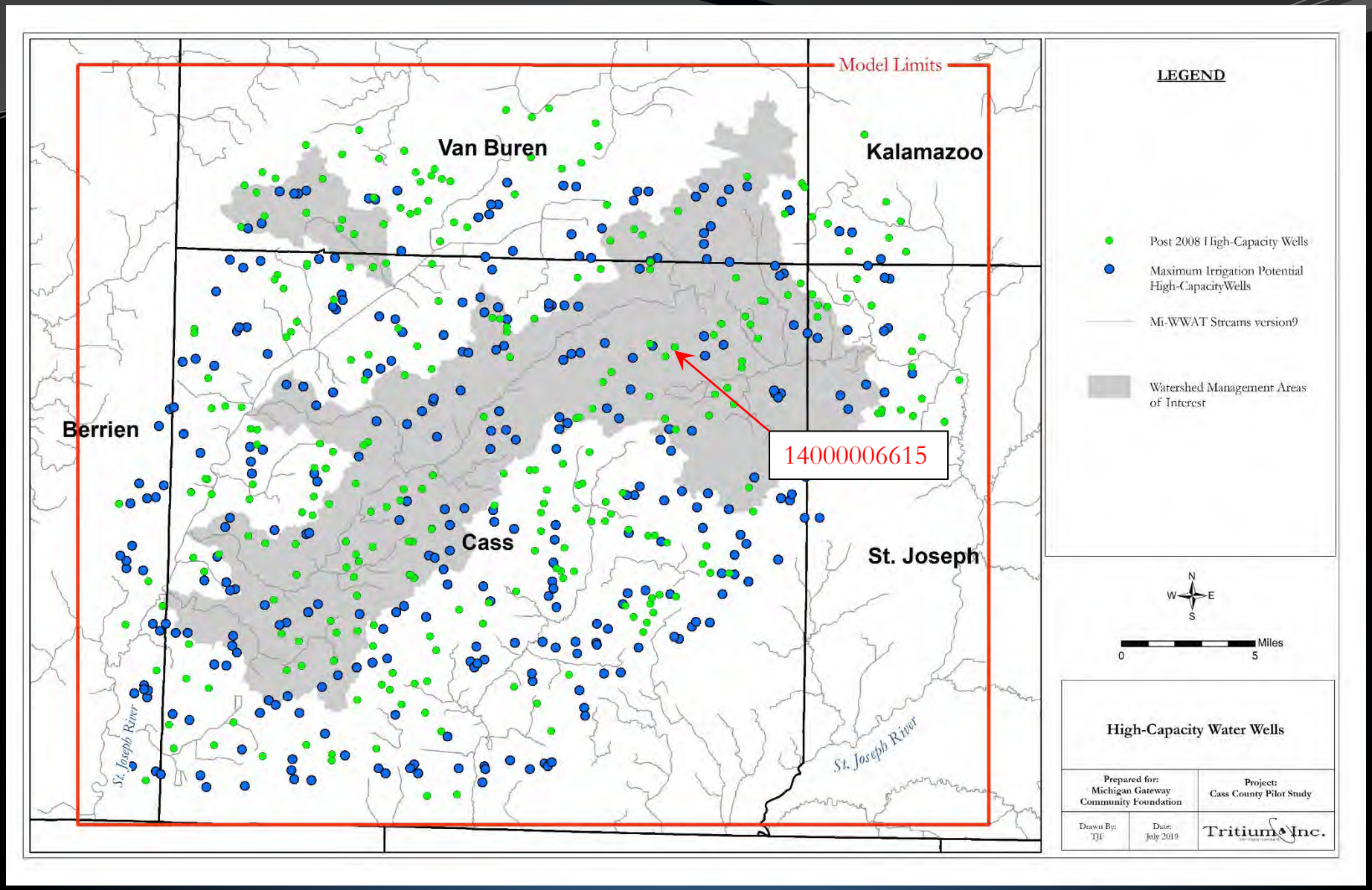
1. Groundwater Contour Comparison
2. Residual Analyses
3. Statistical Analyses
4. Steady-State Calibration
   - Pilot Project Monitoring Wells
   - Esch Water Levels
   - Wellogic Wells
5. Transient Calibration
   - Streambed flux
   - Stream discharge
   - Spring, Summer, Fall, and Winter water levels
6. Comparison to other Regional Models
7. Independent Peer Review

MODEL SIMULATIONS

- Steady-State
- Current Irrigation
- Maximum Irrigation
- Cyclical Pumping versus Constant Rate
- Variable Monthly Recharge with No Pumping
- Increased Recharge for Long-term Precipitation
- Return Flow of 15%
- Added Minor Tributaries

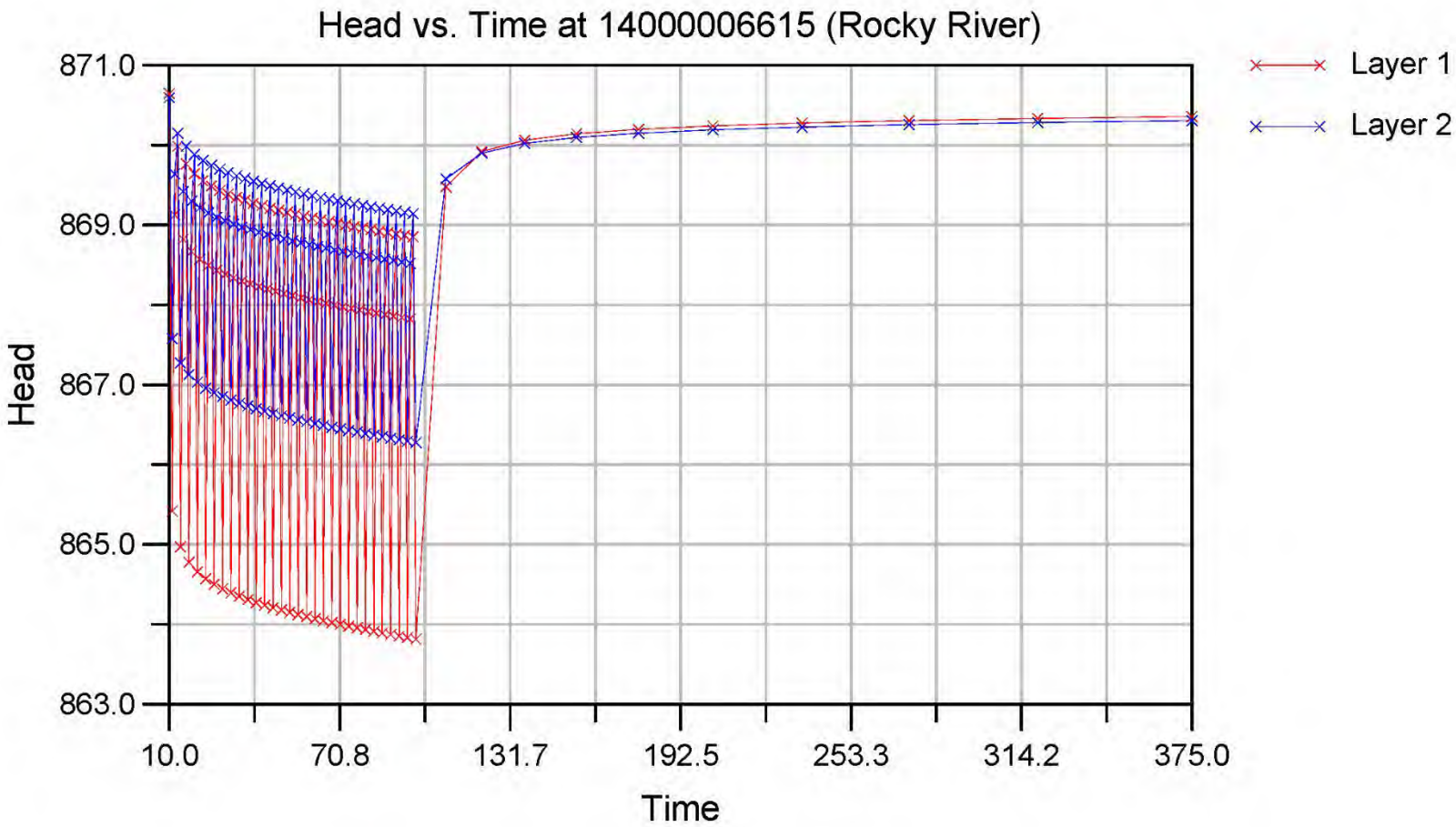


EXISTING CROP IRRIGATION (AS OF SEPTEMBER, 2019)

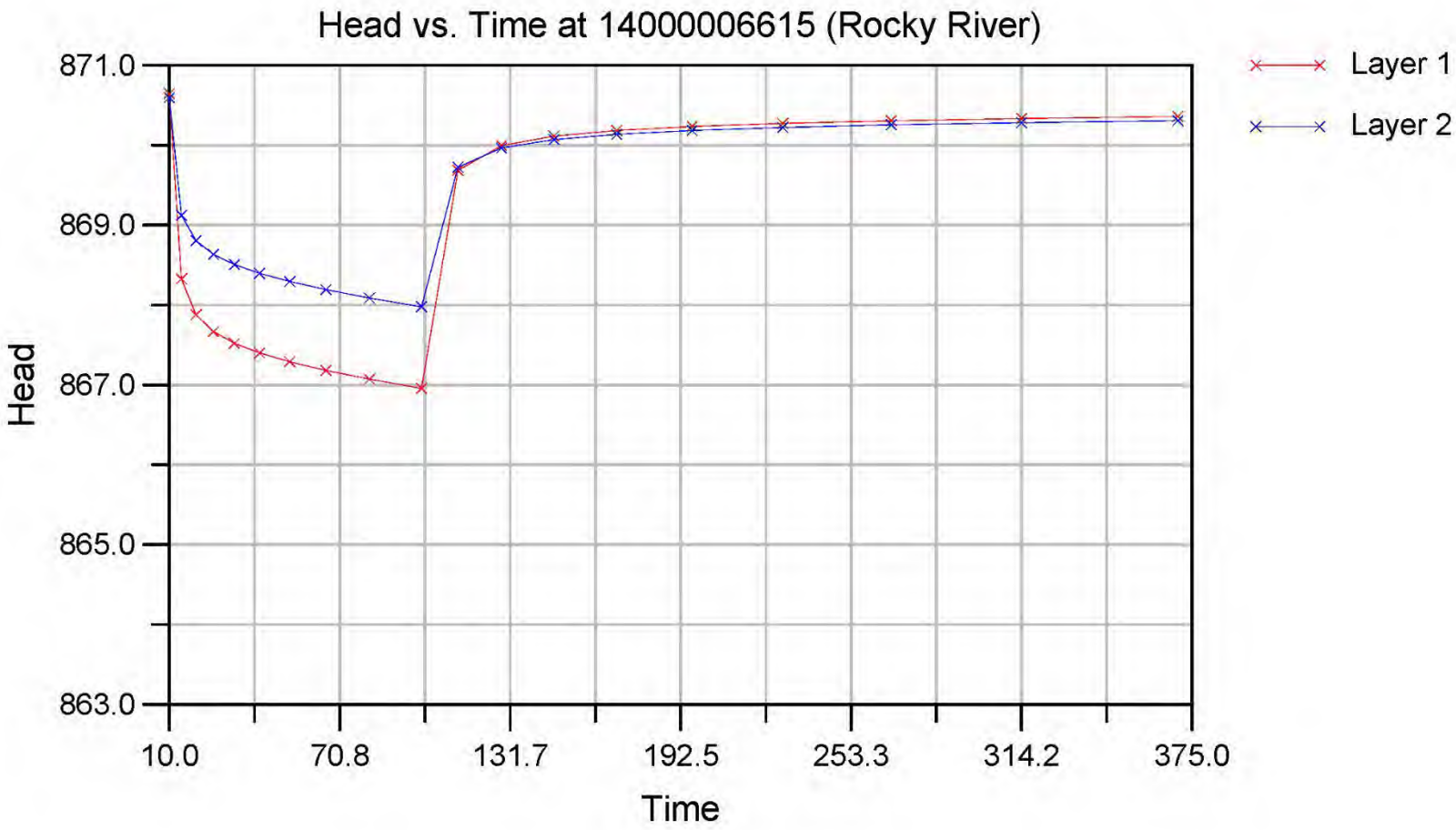


MAXIMUM POTENTIAL CROP IRRIGATION

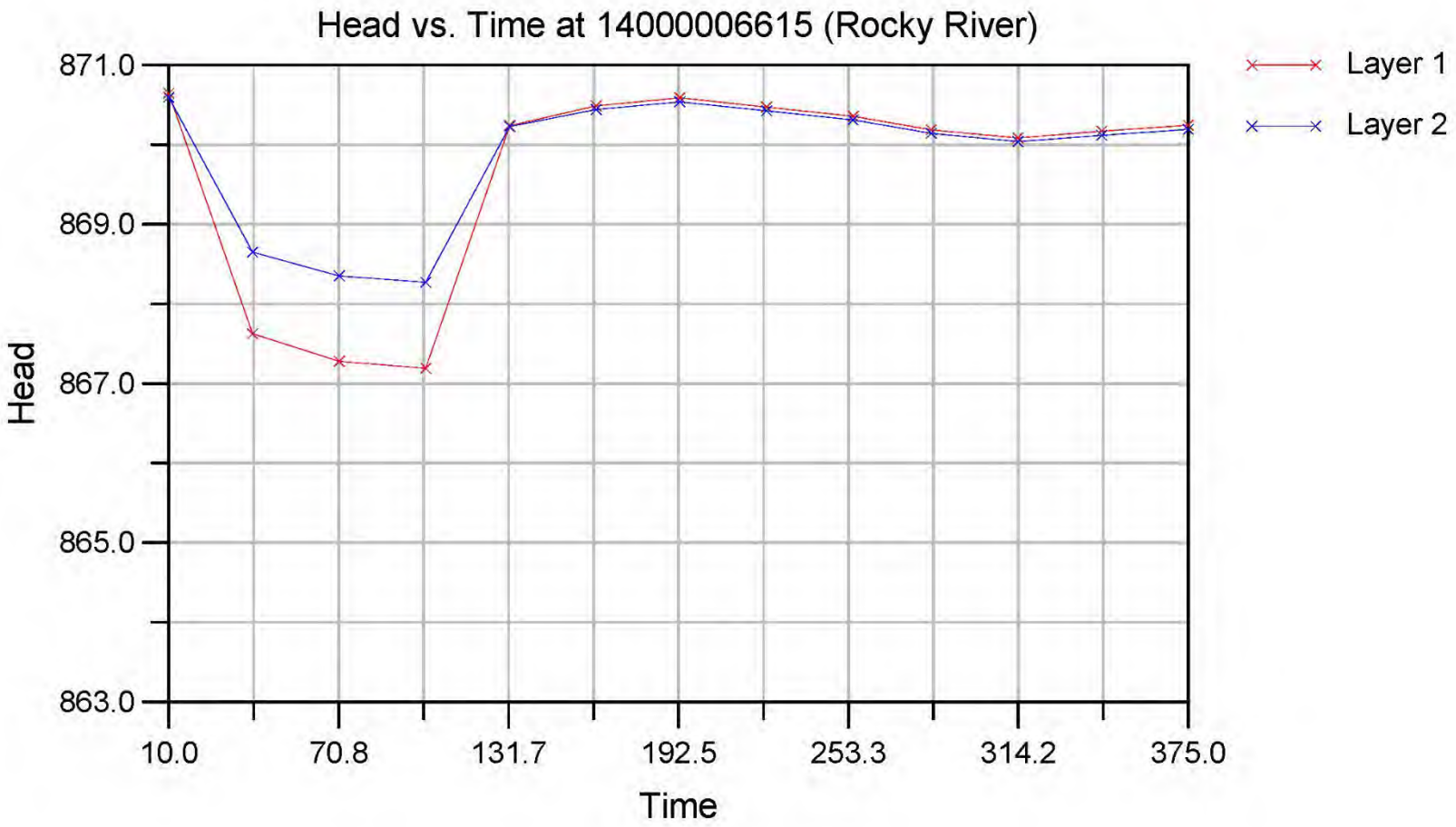
CYCLICAL PUMPING – 1 YEAR



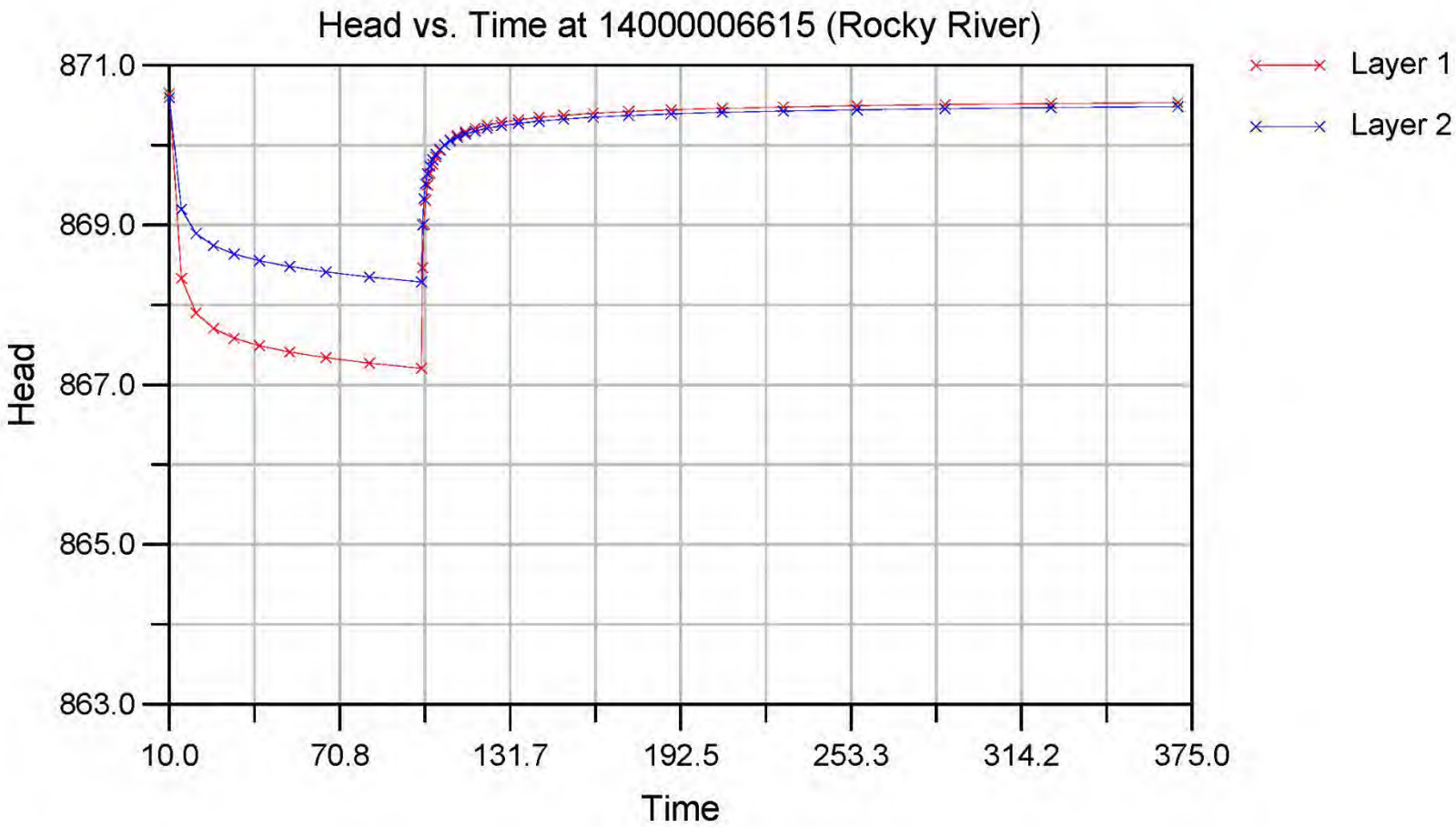
CONSTANT RATE PUMPING – 1 YEAR



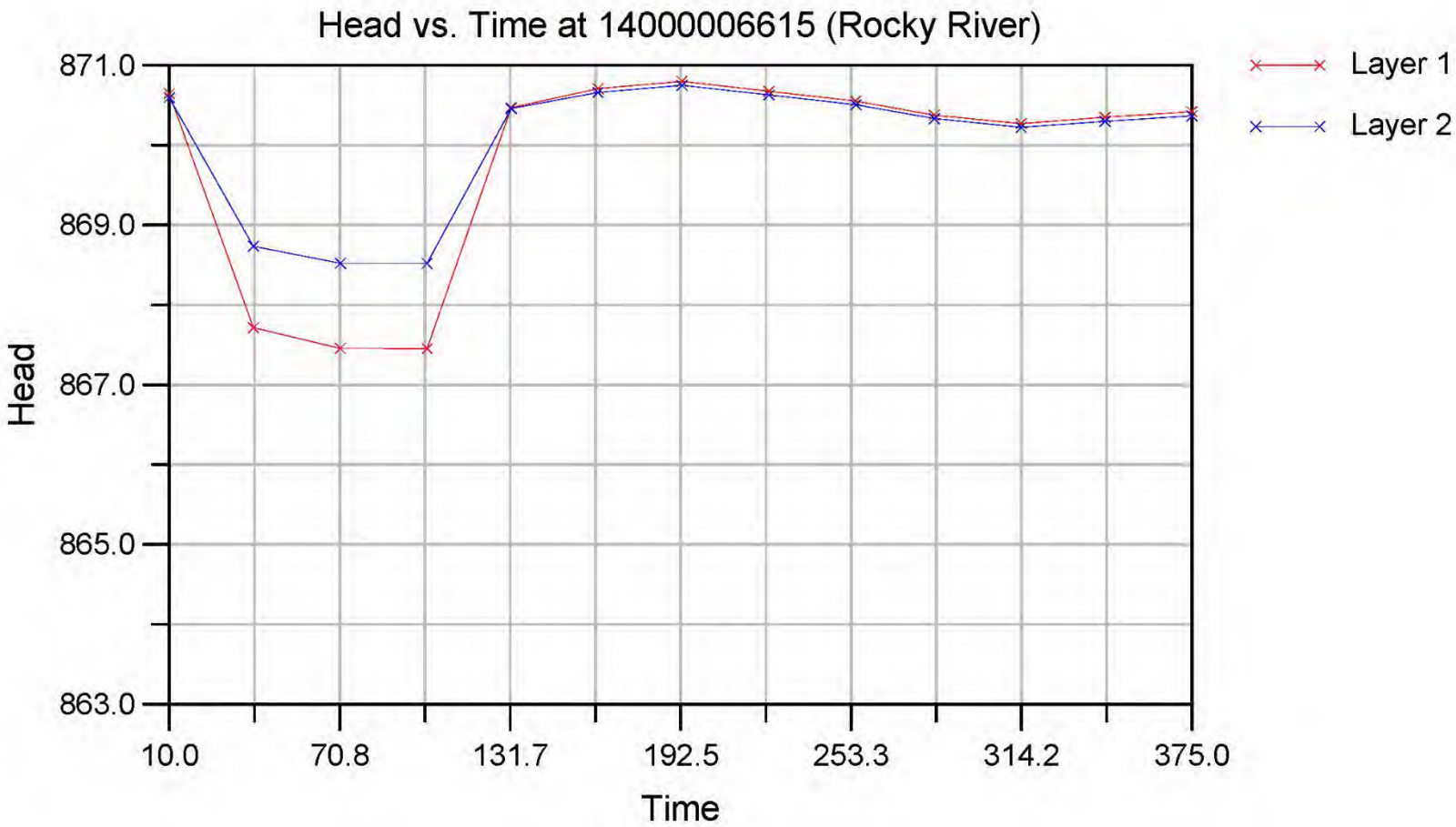
CONSTANT RATE PUMPING WITH SEASONAL RECHARGE– 1 YEAR



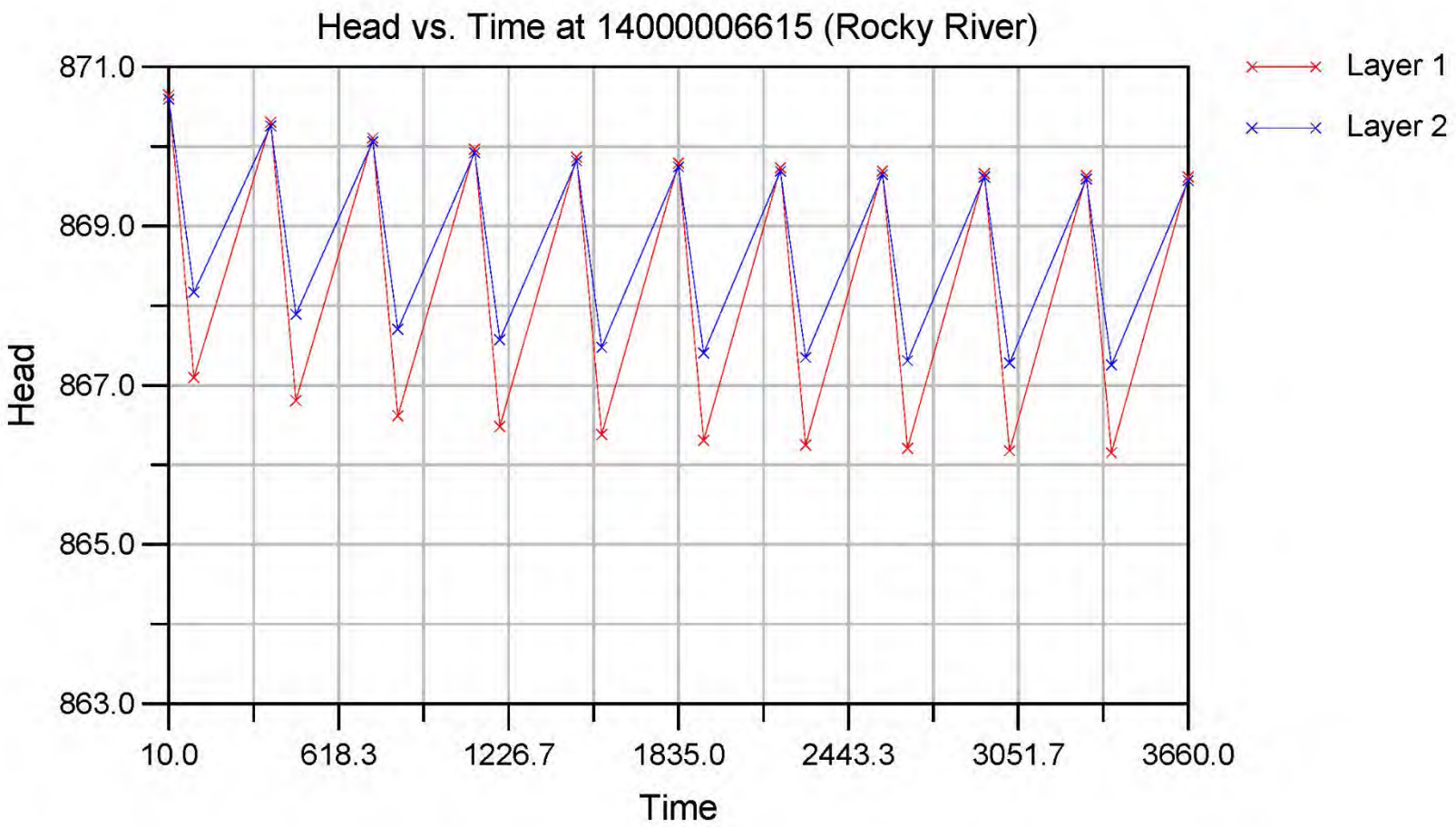
CONSTANT RATE PUMPING WITH RETURN FLOW– 1 YEAR



CONSTANT RATE PUMPING WITH SEASONAL RECHARGE AND RETURN FLOW– 1 YEAR

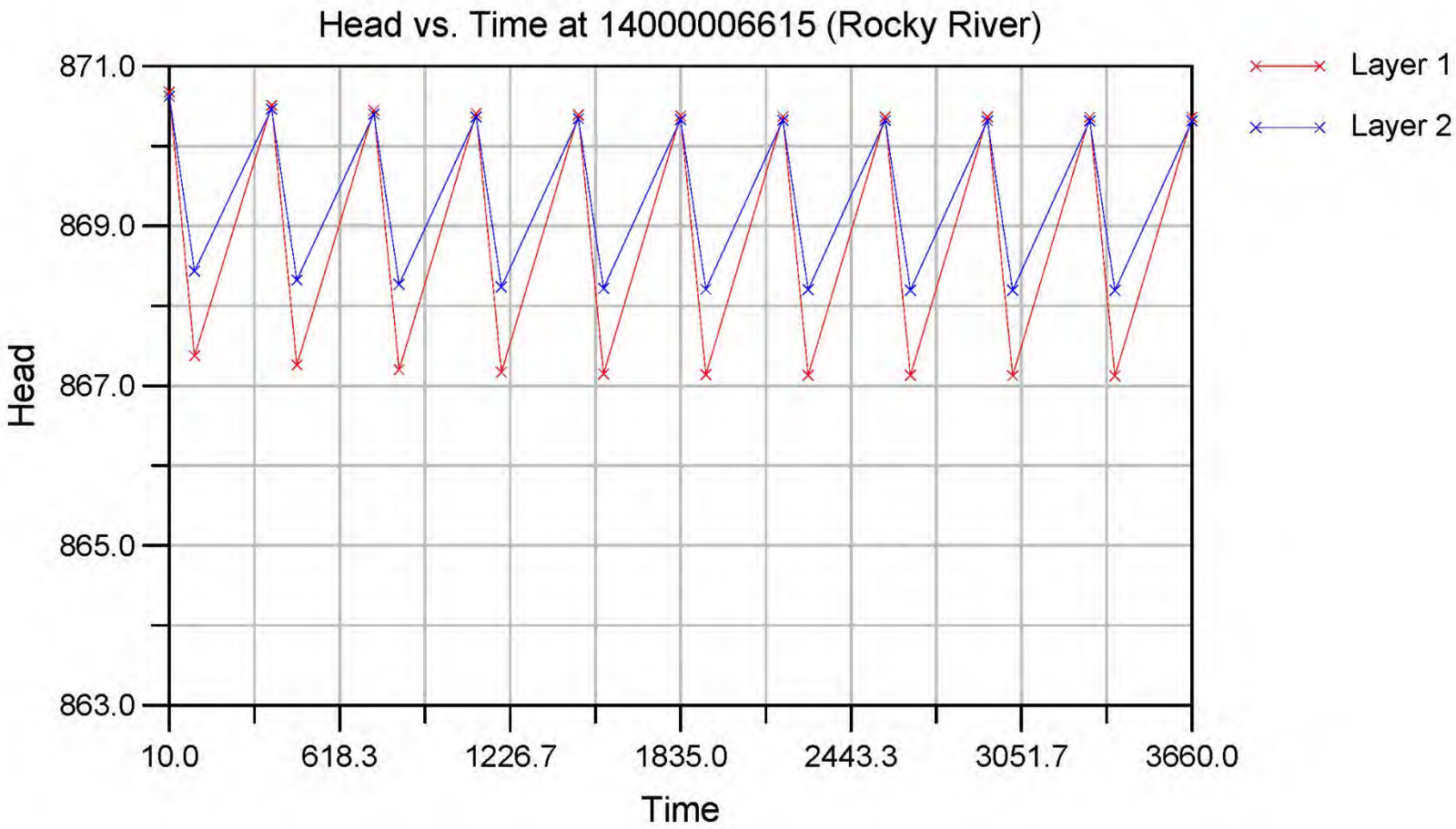


CURRENT IRRIGATION – 10 YEARS



ASSUMES CONSTANT RAINFALL BASED ON 30-YEAR AVERAGE

CURRENT IRRIGATION WITH RETURN FLOW – 10 YEARS



ASSUMES CONSTANT RAINFALL BASED ON 30-YEAR AVERAGE

END OF IRRIGATION SEASON

CURRENT IRRIGATION

Reach	River	Zone D Cutoff	Post-2008 Streamflow Depletion	Add Return Flow And Seasonal Recharge Streamflow Depletion
9	Dowagiac Creek	25%	-2.50%	5.0%
10	Dowagiac Creek	4%	-3.10%	6.0%
11	Dowagiac Creek	25%	-2.50%	2.9%
12	Dowagiac Creek	25%	-3.10%	4.6%
13	Mckenzie Creek	20%	-3.70%	5.1%
14	Osborn Drain	4%	-13.70%	-2.4%
15	Pokagon Creek	20%	-10.00%	2.2%
16	Rocky River	25%	-3.90%	1.7%
17	Rocky River	17%	-5.20%	1.6%

END OF YEAR

CURRENT IRRIGATION

Reach	River	Zone D Cutoff	Post-2008 Streamflow Depletion	Add Return Flow And Seasonal Recharge Streamflow Depletion
9	Dowagiac Creek	25%	-3.1%	-2.6%
10	Dowagiac Creek	4%	-1.5%	-2.0%
11	Dowagiac Creek	25%	-1.3%	-1.8%
12	Dowagiac Creek	25%	-1.5%	-2.3%
13	Mckenzie Creek	20%	-1.1%	-1.6%
14	Osborn Drain	4%	-3.9%	-3.7%
15	Pokagon Creek	20%	-2.5%	-3.2%
16	Rocky River	25%	-1.8%	-1.5%
17	Rocky River	17%	-1.9%	-2.0%

END OF 5 YEARS

CURRENT IRRIGATION

Reach	River	Zone D Cutoff	Post-2008 Streamflow Depletion	Add Return Flow And Seasonal Recharge Streamflow Depletion
9	Dowagiac Creek	25%	-8.2%	-1.9%
10	Dowagiac Creek	4%	-3.7%	-0.8%
11	Dowagiac Creek	25%	-3.0%	-1.3%
12	Dowagiac Creek	25%	-3.0%	-1.2%
13	Mckenzie Creek	20%	-2.8%	-0.5%
14	Osborn Drain	4%	-9.0%	-0.9%
15	Pokagon Creek	20%	-6.0%	-3.1%
16	Rocky River	25%	-4.2%	-0.9%
17	Rocky River	17%	-3.4%	-0.6%

MAJOR MODELING CONCLUSIONS

1. 80% aquifer storage and 20% streamflow depletion
2. Total rainfall differences in consecutive years is critical
3. Annual timing and magnitude of rainfall events is important
4. Return flow significantly effects storage and depletion
5. Groundwater monitoring is essential

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Southwest Michigan Farmer's for Responsible Water Use (SMF)

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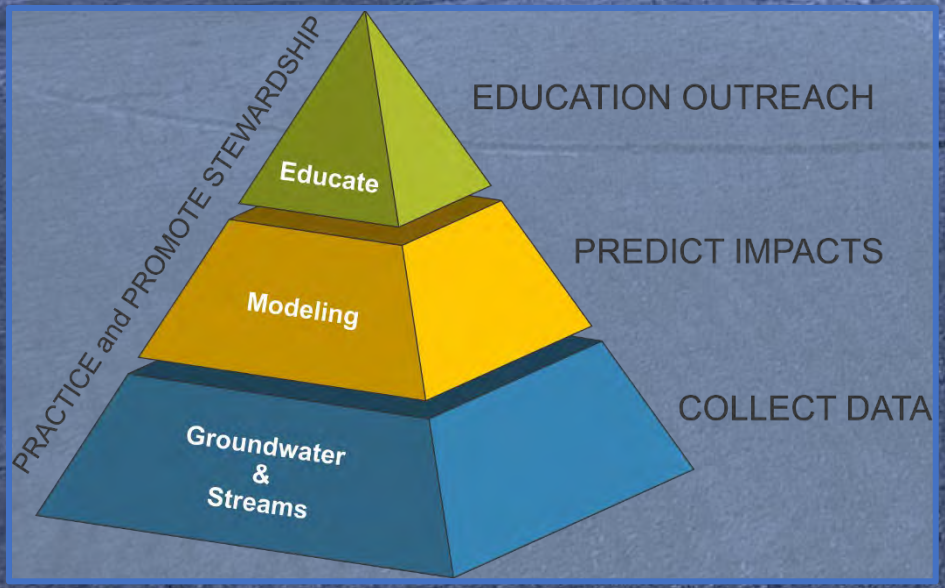
Sunnybrook Farms
Central Produce Supply

"It is the mark of the instructed mind to rest satisfied with the degree of precision which the subject permits … and not to seek an exactness where only an approximation of the truth is possible." Aristotle

MIDWEST WATER STEWARDS
The Stewardship Standard

MISSION STATEMENT

PRACTICE AND PROMOTE STEWARDSHIP OF MICHIANA'S WATER RESOURCES.