Multiple Sources and One Pipe: Using Hydraulic Analysis to Model Source Water Composition Changes in the Arkell Aqueduct

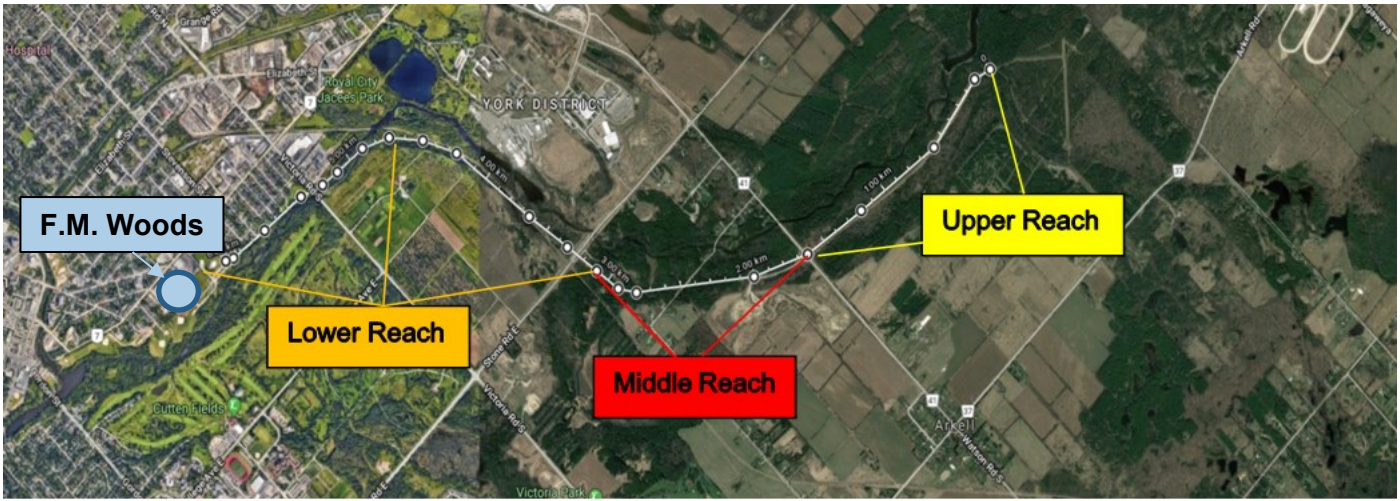
CITY OF Guelph
Making a Difference

C3 WATER

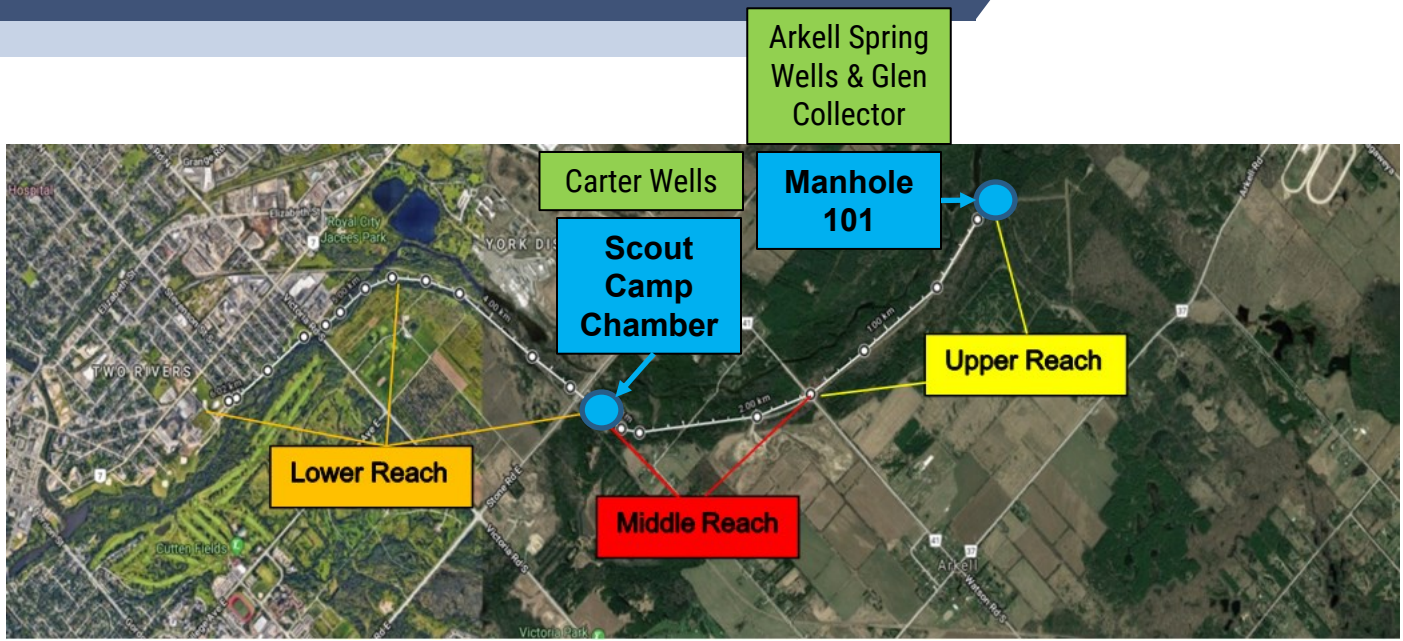
Background

The Arkell Aqueduct and F.M. Woods Water Treatment Plant

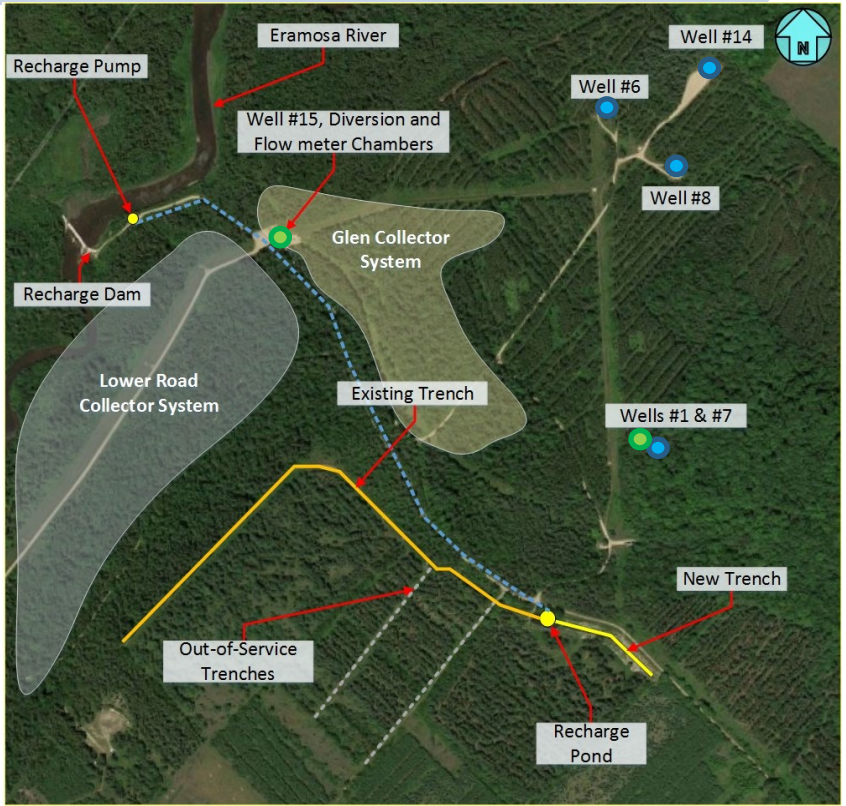
Arkell Aqueduct



Water Sources

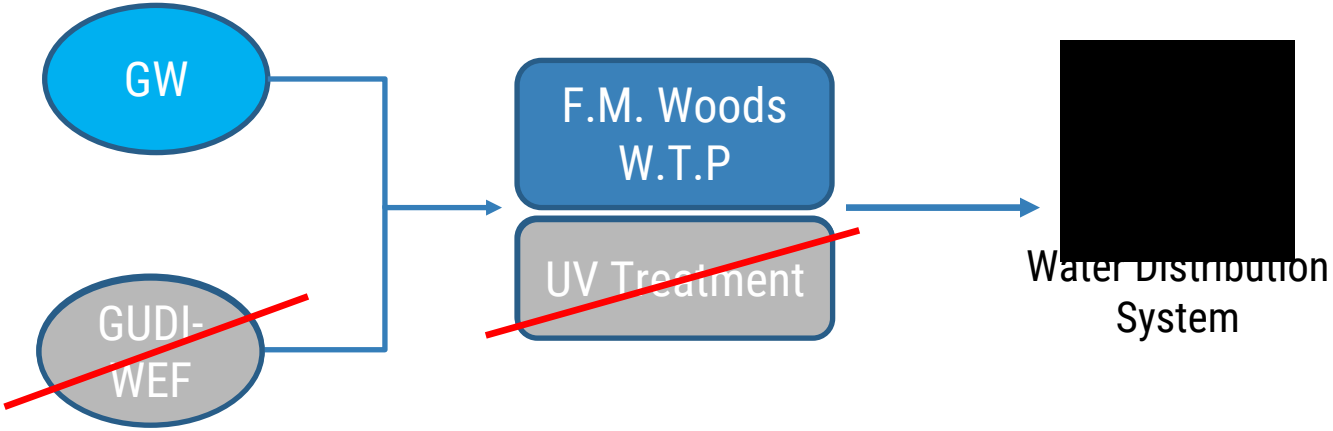


Water Sources



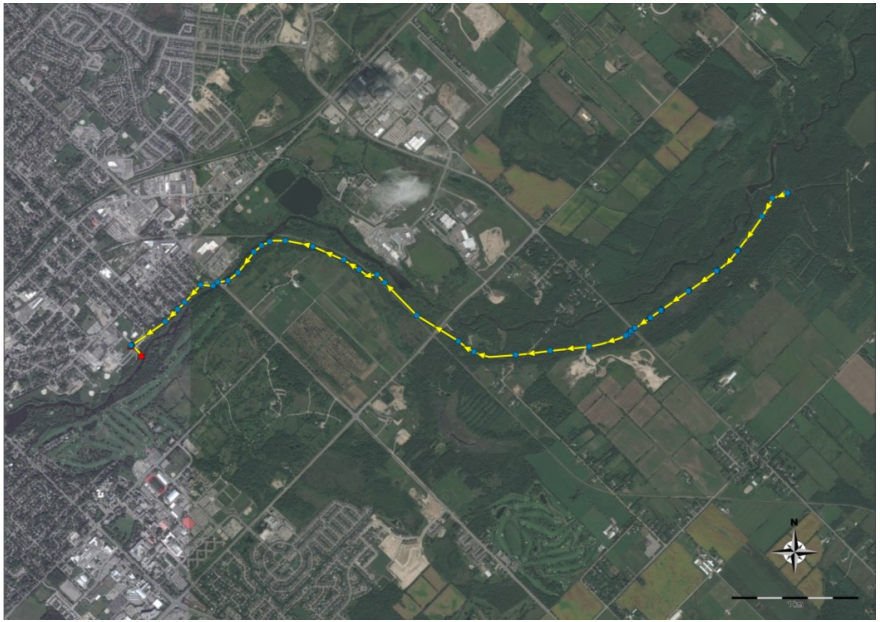
- Groundwater (GW)
- Groundwater Under the Direct Influence of Surface Water with Effective Filtration (GUDI-WEF)

Treatment


GW
GUDI-WEF
F.M. Woods W.T.P
UV Treatment
[redacted]
Water Distribution System

Model Development

Model



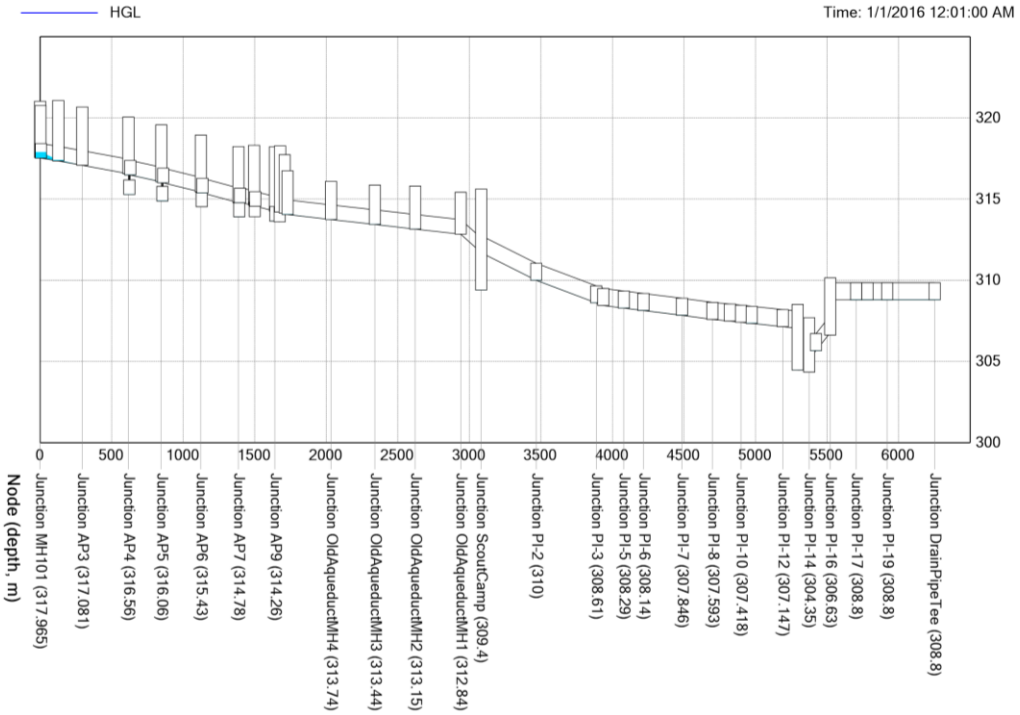
Goals:

- Isolate and drain the aqueduct
- Introduce only GW sources

Assess:

- Risk of manhole flooding during draining
- GW source interface time of travel

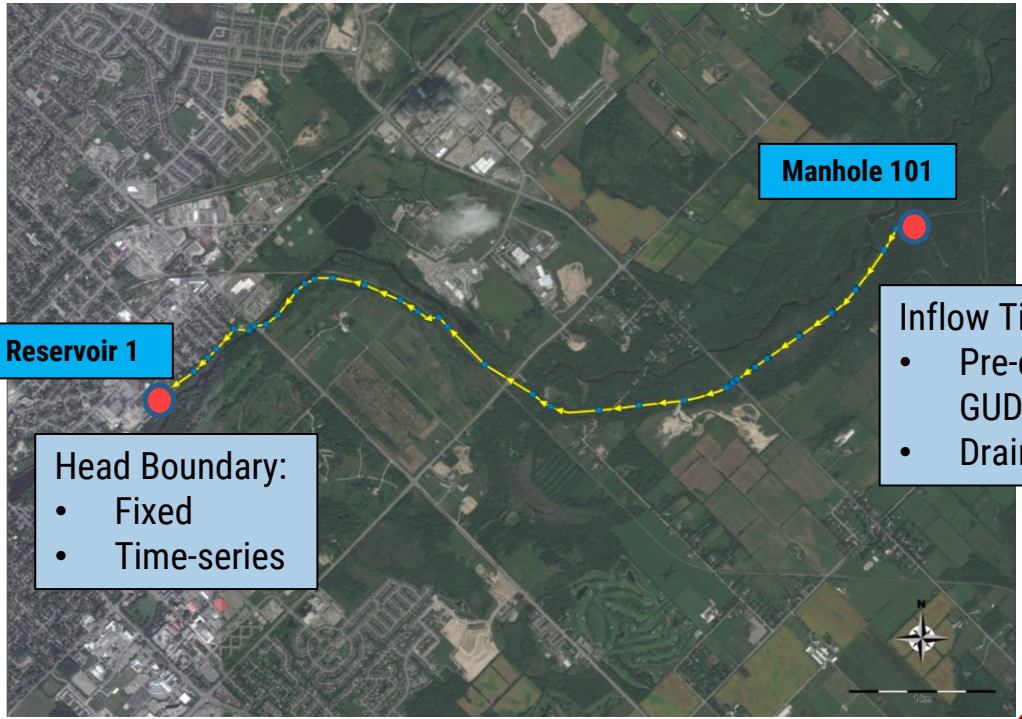
Model Development



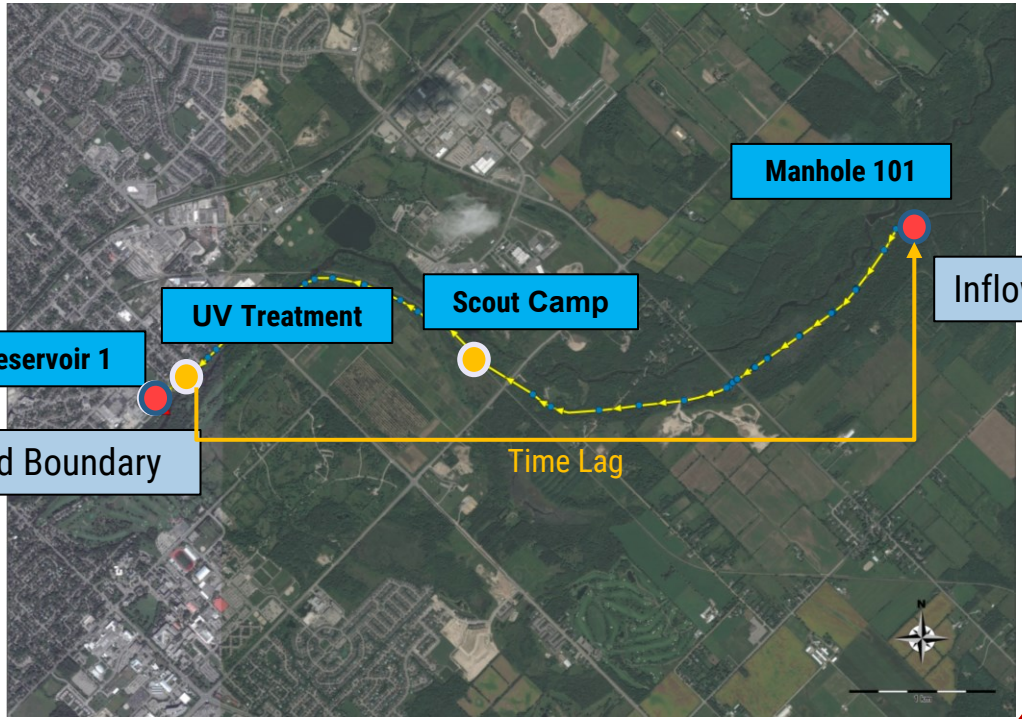
Equations:

- Darcy-Weisbach
- Manning's

Model Inputs



Model Calibration



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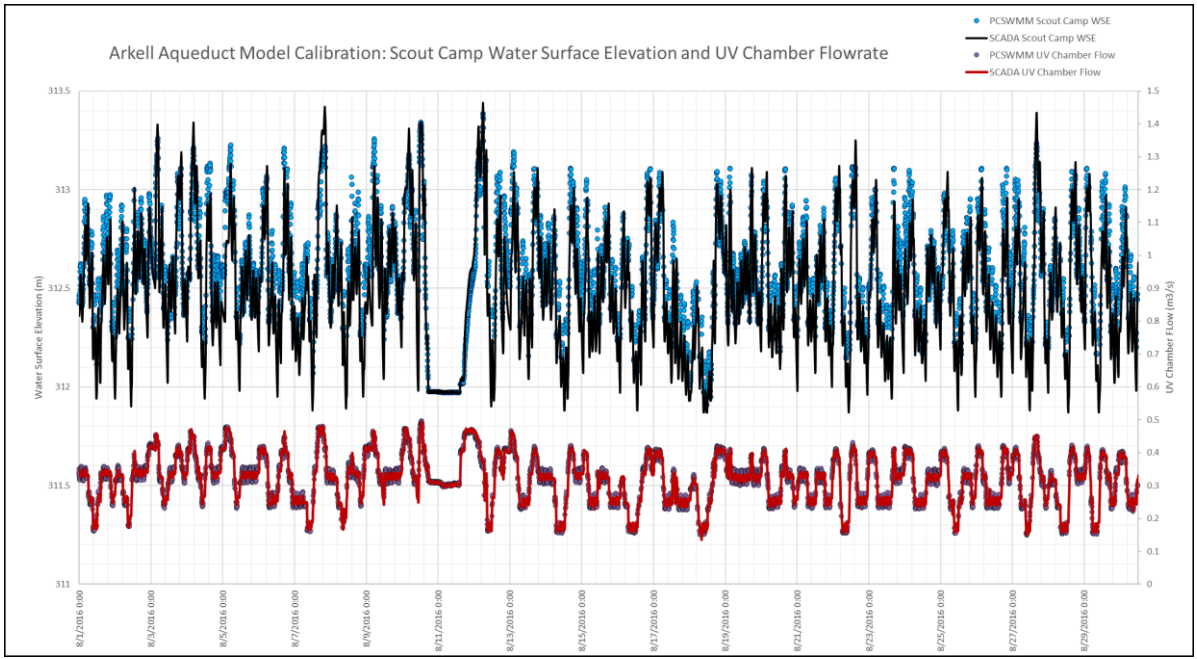
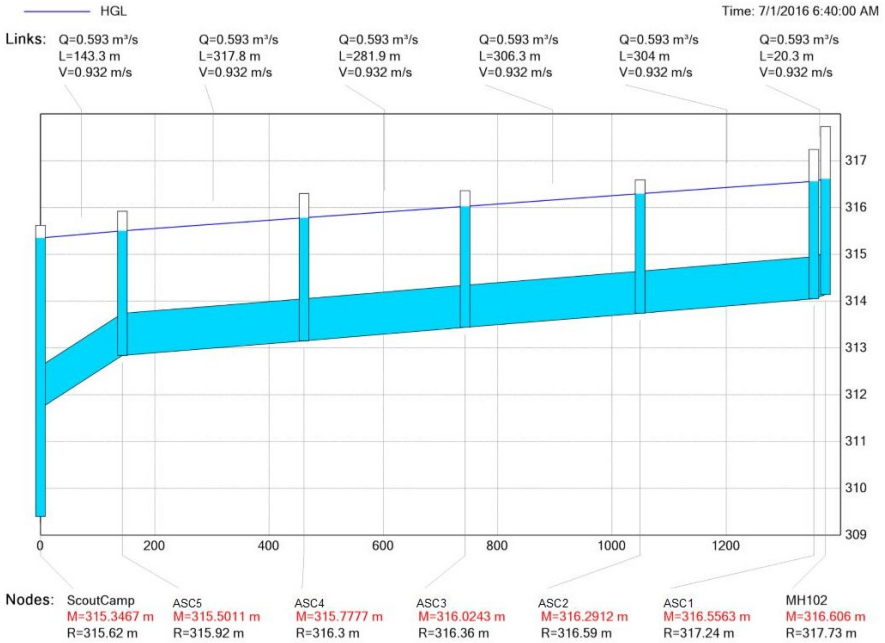
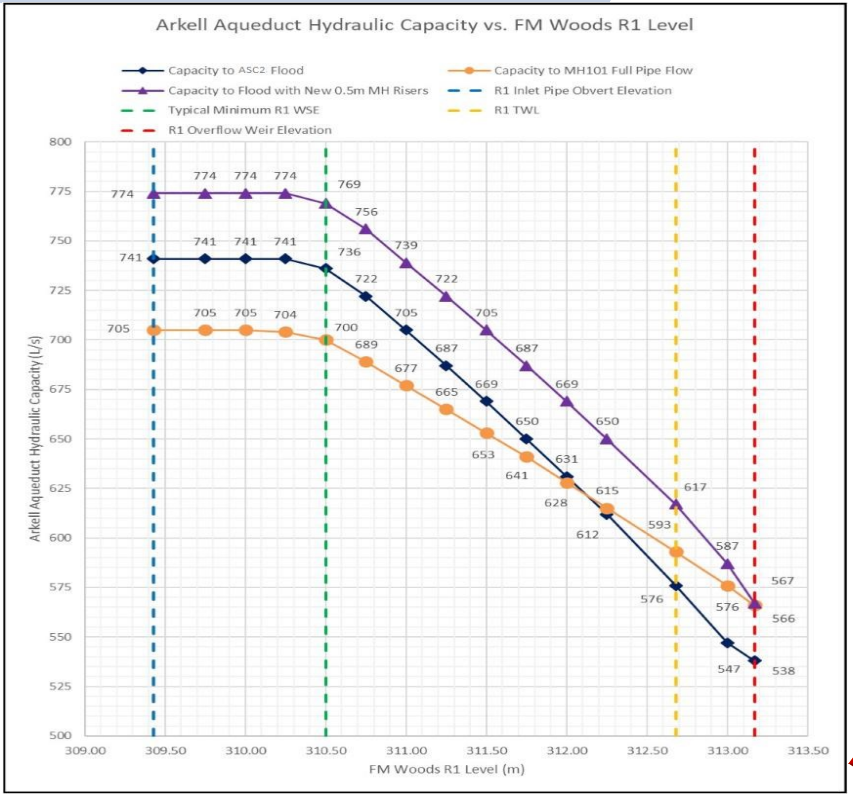


Model Results

Hydraulic Capacity and Flood Risk



Hydraulic Capacity and Flood Risk



Draining Time

Planned UV Shutdown

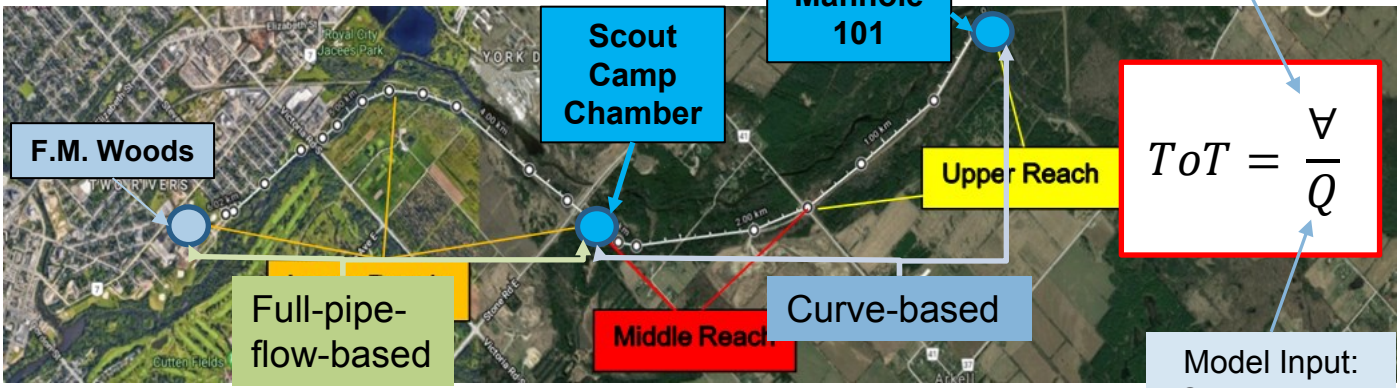
- Remove GUDI-WEF sources
- Time for initial GW + GUDI-WEF storage volume to clear aqueduct

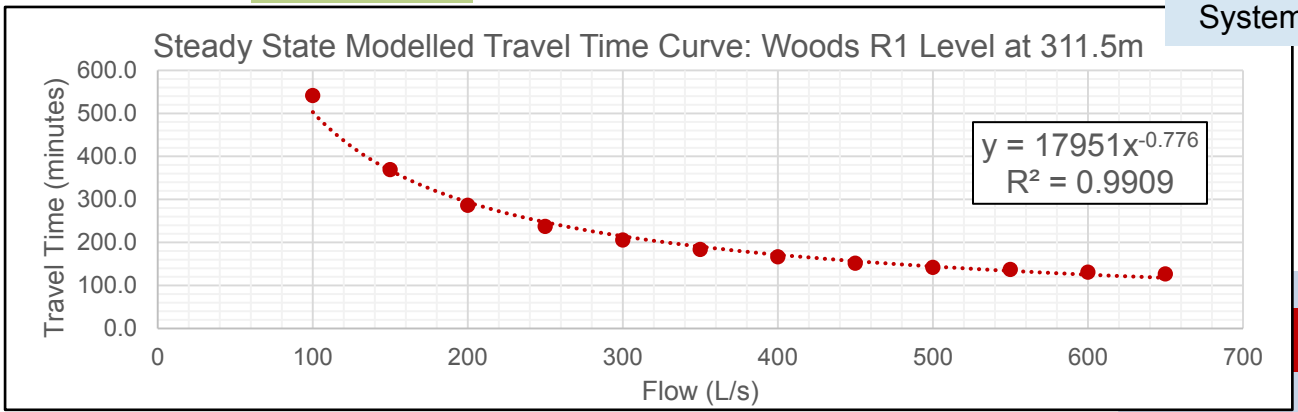
Emergency UV Shutdown

- Aqueduct isolation butterfly valves will close at F.M. Woods
- Aqueduct drain line into Eramosa River will open
- Remove GUDI-WEF sources

Time of Travel

Model Output: Pipe Storage Volume



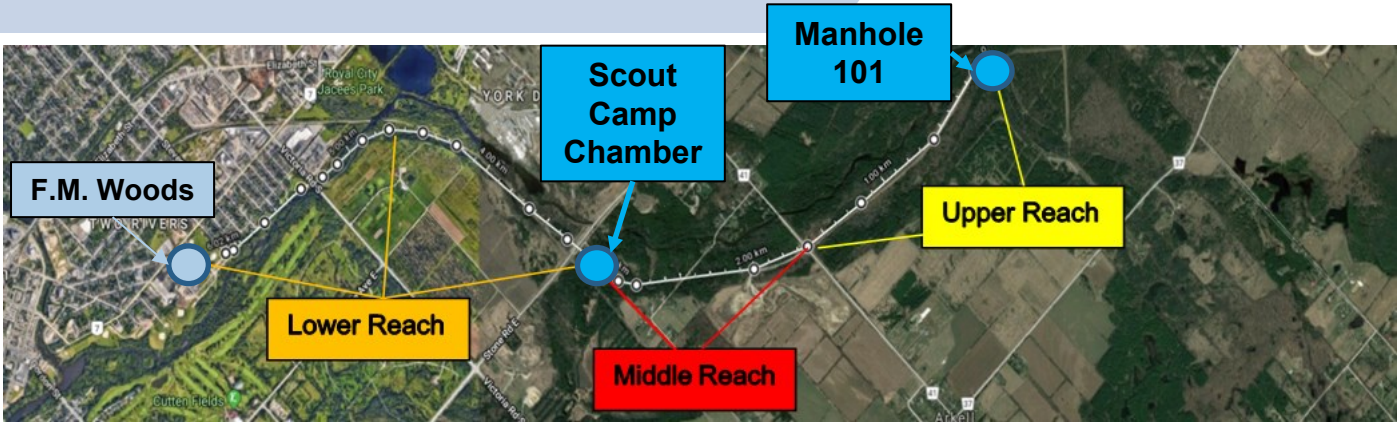


SOURCE WATER CHARACTERIZATION AND PCN

PCN Development

- Develop travel time curves for the aqueduct using the PCSMM model
- Determine when a GUDIWEF or GW changeover occurs at production
- Determine when the GUDIWEF/GW interface will reach treatment
- Update SCADA output real-time to reflect what is actually being treated and when a change-over is estimated to occur

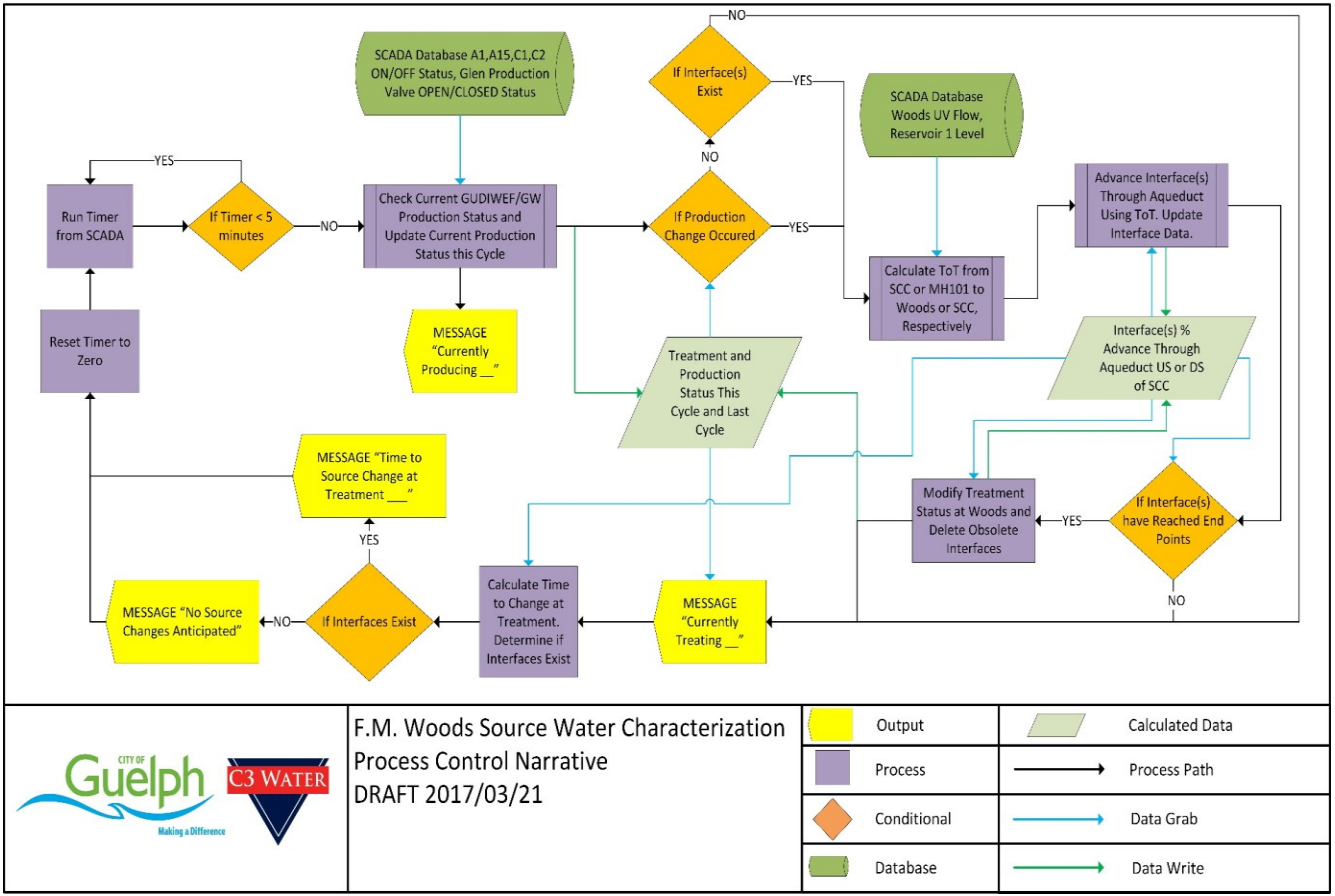
Time of Travel



$$\sum_{i=0}^{t} \frac{\Delta t}{ToT_i} = \text{Cumulative percentage advance (dimensionless)}$$

Where:

- Δt = Time elapsed since last routine (5 minutes)
- ToT_i = Calculated time of travel from SCC to Woods, or from MH101 to SCC in minutes


SCADA Database A1,A15,C1,C2 ON/OFF Status, Glen Production Valve OPEN/CLOSED Status
If Interface(s) Exist
NO
YES
SCADA Database Woods UV Flow, Reservoir 1 Level
Advance Interface(s) Through Aqueduct Using ToT. Update Interface Data.
Run Timer from SCADA
YES
If Timer < 5 minutes
NO
Check Current GUDIWEF/GW Production Status and Update Current Production Status this Cycle
If Production Change Occured
YES
NO
Calculate ToT from SCC or MH101 to Woods or SCC, Respectively
Reset Timer to Zero
MESSAGE "Currently Producing __"
Treatment and Production Status This Cycle and Last Cycle
Interface(s) % Advance Through Aqueduct US or DS of SCC
MESSAGE "Time to Source Change at Treatment ___"
YES
Modify Treatment Status at Woods and Delete Obsolete Interfaces
YES
If Interface(s) have Reached End Points
NO
MESSAGE "No Source Changes Anticipated"
NO
If Interfaces Exist
Calculate Time to Change at Treatment. Determine if Interfaces Exist
MESSAGE "Currently Treating __"
F.M. Woods Source Water Characterization
Process Control Narrative
DRAFT 2017/03/21
Output
Process
Conditional
Database
Calculated Data
Process Path
Data Grab
Data Write

AUTOMATION

How do I program this into SCADA?

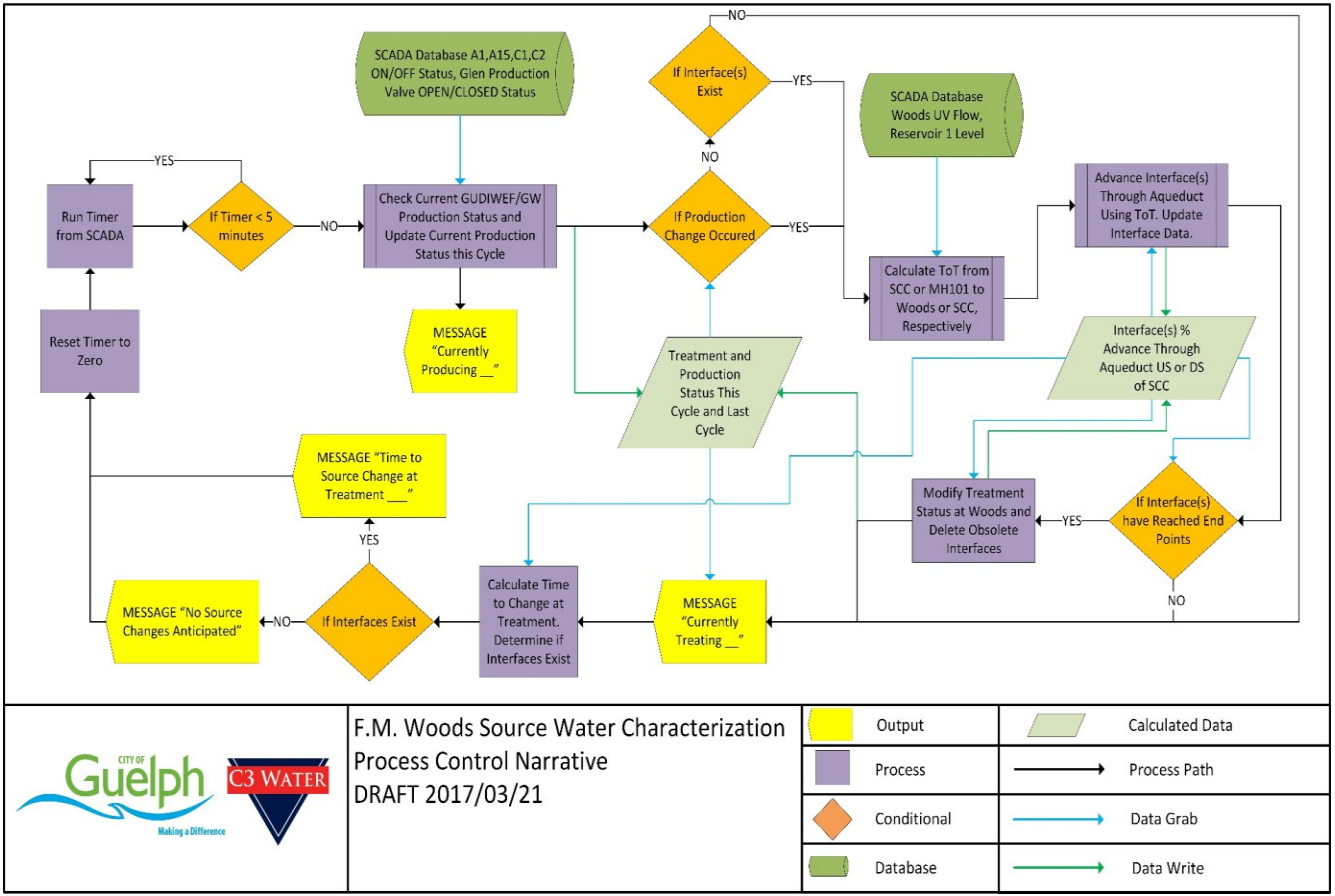
- How are operators going to use this tool?
- Process data inputs?
- Expected outputs?

- Design of user interface on screen?
- How do I structure the internal PLC code?
- How to fit this within the existing SCADA System?

- **How can I test/verify the code?**

PCN to SCADA Programming

- We found the flowchart PCN provided a good operational description for people to understand how the flow model would work
- **But…**
  The algorithm in the PCN would be very hard to test, as it has multiple decision structures/calculations that run every 5 mins
- Changed PCN algorithm into a step-wise Excel-based model
- Resulting Excel spreadsheet:
  - Each row is a 5 min iteration
  - 52 columns: 7 inputs, 37 internal-calcs/if-then, 8 outputs
  - Uses standard Excel functions (no VB or macros)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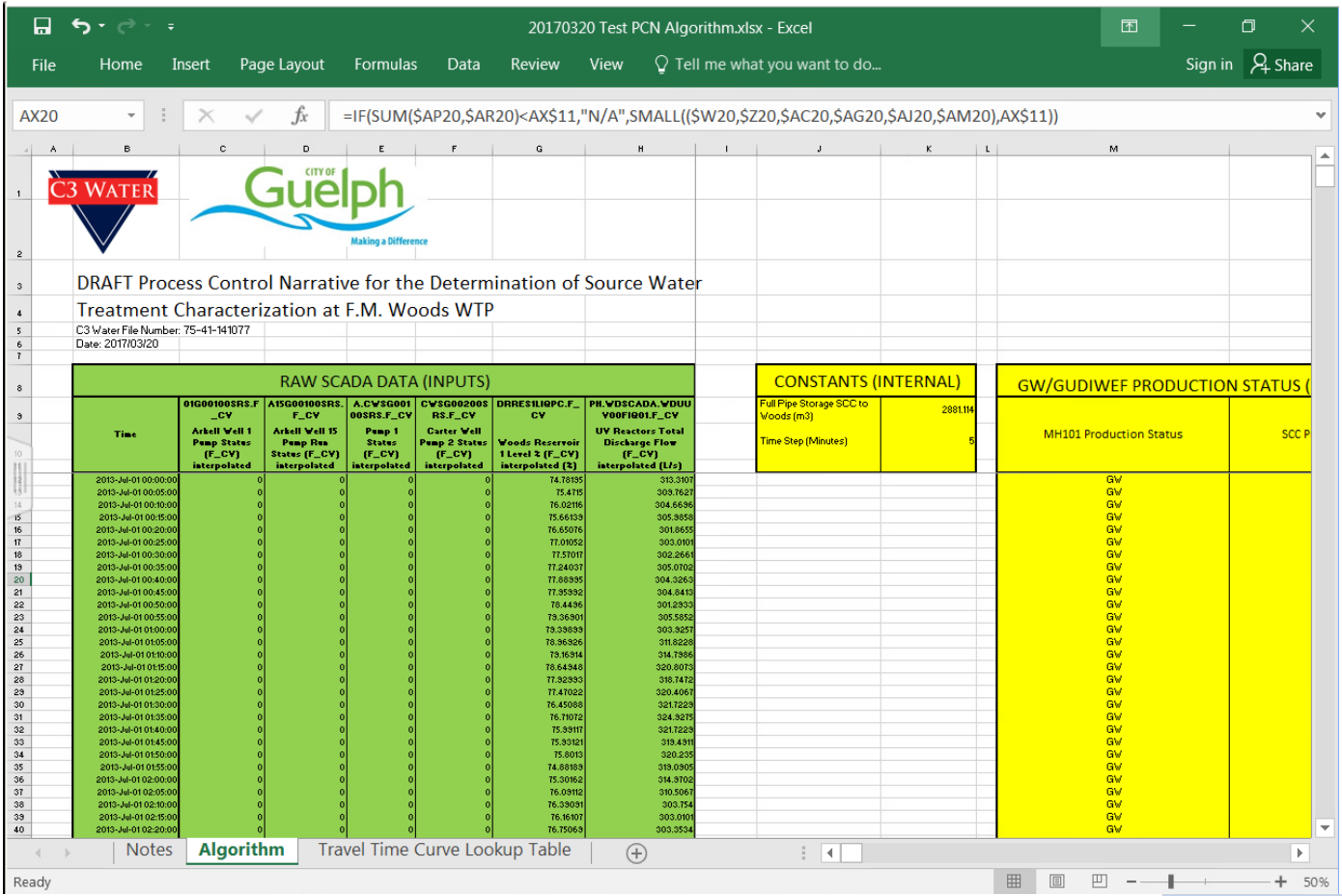

20170320 Test PCN Algorithm.xlsx - Excel

File Home Insert Page Layout Formulas Data Review View Tell me what you want to do... Sign in Share

AX20 =IF(SUM($AP20,$AR20)<AX$11,"N/A",SMALL(($W20,$Z20,$AC20,$AG20,$AJ20,$AM20),AX$11))

C3 WATER

CITY OF Guelph Making a Difference

DRAFT Process Control Narrative for the Determination of Source Water Treatment Characterization at F.M. Woods WTP

C3 Water File Number: 75-41-141077

Date: 2017/03/20

RAW SCADA DATA (INPUTS)

Time	01G00100SRS.F_CV Arkell Well 1 Pump States (F_CV) interpolated	A15G00100SRS.F_CV Arkell Well 15 Pump Run States (F_CV) interpolated	A.CWSG00100SRS.F_CV Pump 1 Status (F_CV) interpolated	CWSG00200SRS.F_CV Carter Well Pump 2 States (F_CV) interpolated	DRRES1LIQPC.F_CV Woods Reservoir 1 Level % (F_CV) interpolated (%)	PH.WDSCADA.WDUUV00FIQ01.F_CV UV Reactors Total Discharge Flow (F_CV) interpolated (L/s)
2013-Jul-01 00:00:00	0	0	0	0	74.78135	313.3107
2013-Jul-01 00:05:00	0	0	0	0	75.4715	309.7627
2013-Jul-01 00:10:00	0	0	0	0	76.02116	304.6696
2013-Jul-01 00:15:00	0	0	0	0	75.66133	305.9858
2013-Jul-01 00:20:00	0	0	0	0	76.65076	301.8655
2013-Jul-01 00:25:00	0	0	0	0	77.01052	303.0101
2013-Jul-01 00:30:00	0	0	0	0	77.57017	302.2661
2013-Jul-01 00:35:00	0	0	0	0	77.24037	305.0702
2013-Jul-01 00:40:00	0	0	0	0	77.88395	304.3263
2013-Jul-01 00:45:00	0	0	0	0	77.35392	304.8413
2013-Jul-01 00:50:00	0	0	0	0	78.4496	301.2933
2013-Jul-01 00:55:00	0	0	0	0	79.36901	305.5852
2013-Jul-01 01:00:00	0	0	0	0	79.39899	303.9257
2013-Jul-01 01:05:00	0	0	0	0	78.96926	311.8228
2013-Jul-01 01:10:00	0	0	0	0	79.16914	314.7986
2013-Jul-01 01:15:00	0	0	0	0	78.64348	320.8073
2013-Jul-01 01:20:00	0	0	0	0	77.92393	318.7472
2013-Jul-01 01:25:00	0	0	0	0	77.47022	320.4067
2013-Jul-01 01:30:00	0	0	0	0	76.45088	321.7229
2013-Jul-01 01:35:00	0	0	0	0	76.71072	324.3215
2013-Jul-01 01:40:00	0	0	0	0	75.93917	321.7223
2013-Jul-01 01:45:00	0	0	0	0	75.93121	319.4311
2013-Jul-01 01:50:00	0	0	0	0	75.8013	320.235
2013-Jul-01 01:55:00	0	0	0	0	74.88169	319.0305
2013-Jul-01 02:00:00	0	0	0	0	75.30162	314.9702
2013-Jul-01 02:05:00	0	0	0	0	76.03112	310.5067
2013-Jul-01 02:10:00	0	0	0	0	76.33091	303.754
2013-Jul-01 02:15:00	0	0	0	0	76.16107	303.0101
2013-Jul-01 02:20:00	0	0	0	0	76.75063	303.3534

CONSTANTS (INTERNAL)

Full Pipe Storage SCC to Woods (m3)	2881.114
Time Step (Minutes)	5

GW/GUDIWEF PRODUCTION STATUS (

MH101 Production Status	SCC P
GW	
GW	
GW	
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GW	
GW	

Notes Algorithm Travel Time Curve Lookup Table

Ready 50%

Selecting PLC to Use

- Three choices for programming model calculations:
  - Programming in PLC
  - Scripting on a SCADA server
  - Write custom add-on application
- **Selected the PLC-based approach**
  - Had to use a modern PLC. We used a dedicated PLC for project
  - Tag-based memory (not numbered registers)
  - Data Structures (user-defined complex-datatypes) in Arrays
  - Support for “Structured Text” programming
  - Support for user-defined function blocks

Mock-up of SCADA HMI Interface

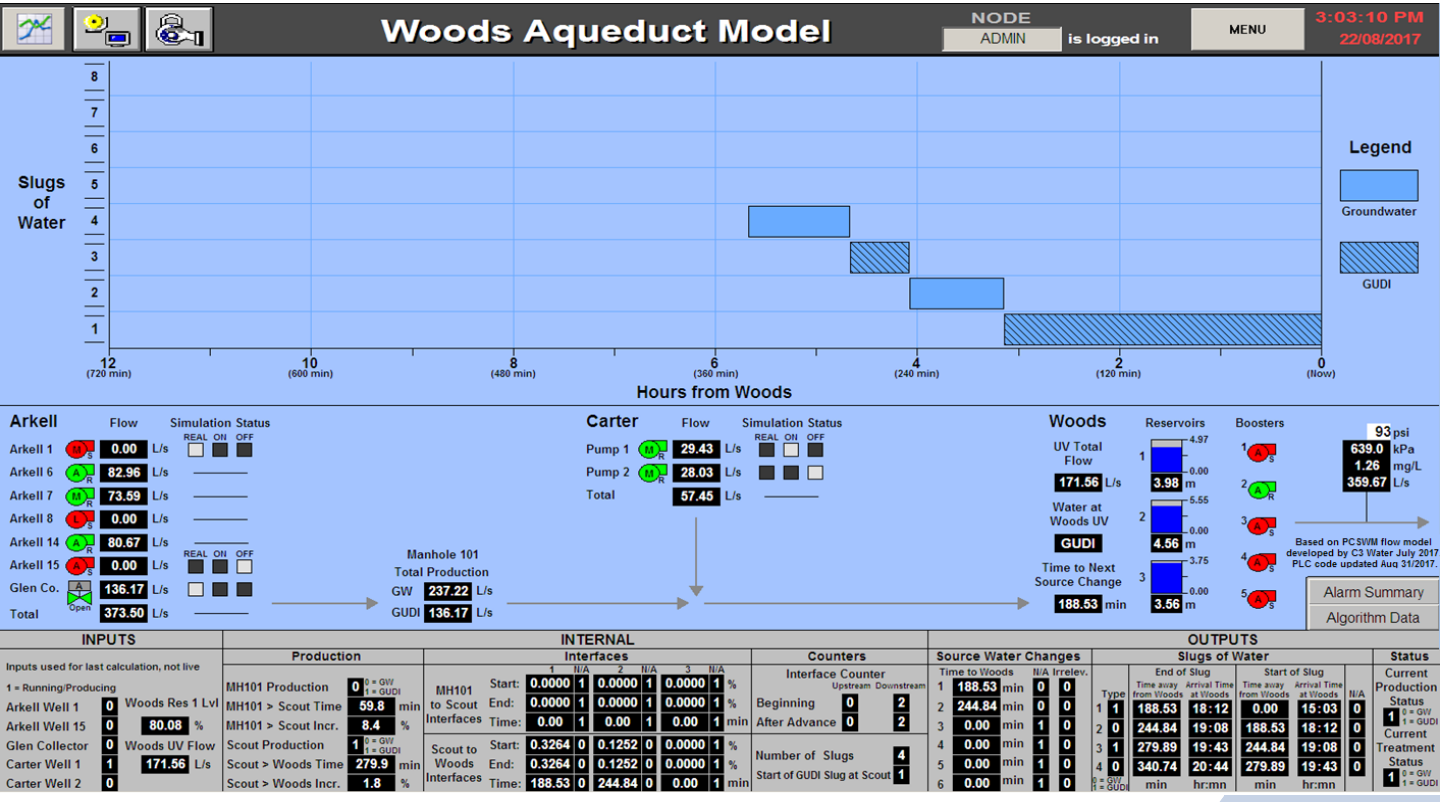
GUDIWEF SOURCE STATUSES AND MANUAL OVERRIDE			
Arkell 1 Status	OFF	Arkell 1 Override	☐
Arkell 15 Status	OFF	Arkell 15 Override	☐
G.C. Prod. Status	OPEN	G.C. Prod. Override	☐
Carter 1 Status	ON	Carter 1 Override	☒
Carter 2 Status	ON	Carter 2 Override	☒

INPUT DATA
(from SCADA)

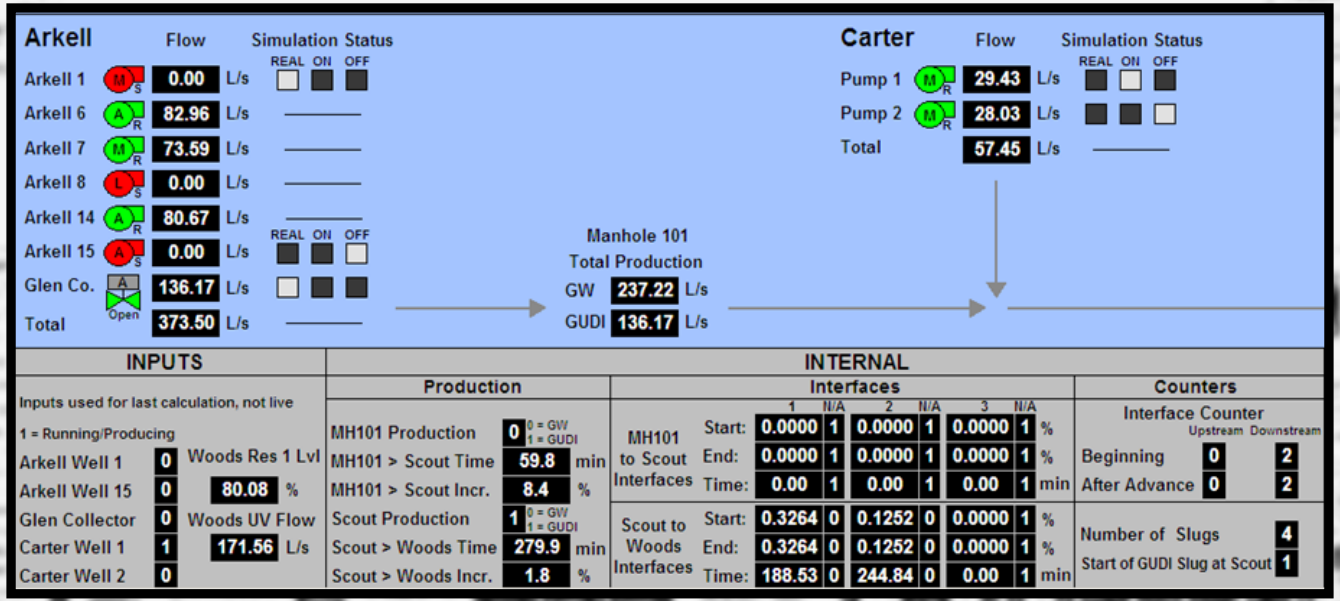
MODEL OUTPUT
(for operators)

CURRENT PRODUCTION SOURCE CHARACTERIZATION	GUDIWEF	
CURRENT TREATMENT SOURCE CHARACTERIZATION	Groundwater	
TIME TO CHANGE IN SOURCE WATER AT TREATMENT	1st Change	150 min
	2nd Change	N/A
	3rd Change	N/A
	4th Change	N/A
	5th Change	N/A
	6th Change	N/A

Final HMI Screen Design



Final HMI Screen Design – MODEL INPUTS & Calcs



Final HMI Screen Design – MODEL OUTPUTS & PLOT

OUTPUTS

Source Water Changes

	Time to Woods		N/A	Irrelev.
1	188.53	min	0	0
2	244.84	min	0	0
3	0.00	min	1	0
4	0.00	min	1	0
5	0.00	min	1	0
6	0.00	min	1	0

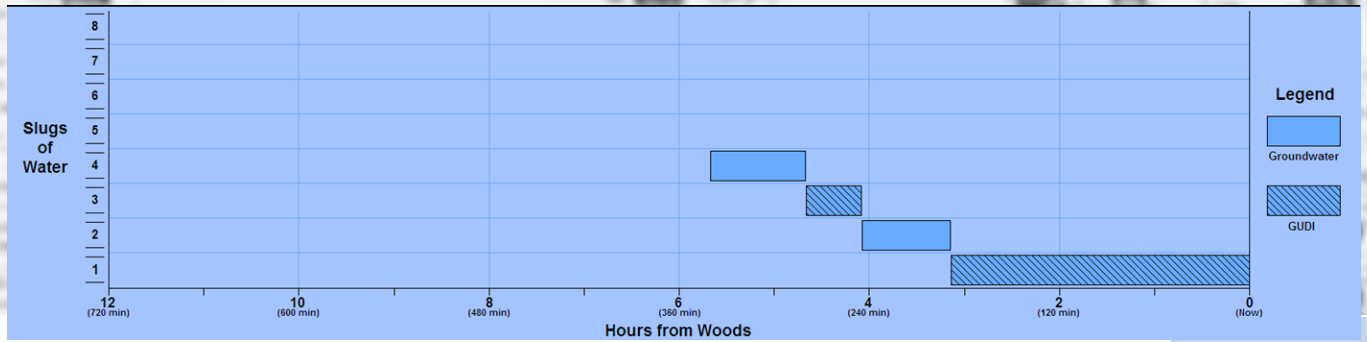
Slugs of Water

	Type	End of Slug: Time away from Woods	End of Slug: Arrival Time at Woods	Start of Slug: Time away from Woods	Start of Slug: Arrival Time at Woods	N/A
1	1	188.53	18:12	0.00	15:03	0
2	0	244.84	19:08	188.53	18:12	0
3	1	279.89	19:43	244.84	19:08	0
4	0	340.74	20:44	279.89	19:43	0
	0 = GW 1 = GUDI	min	hr:mn	min	hr:mn	

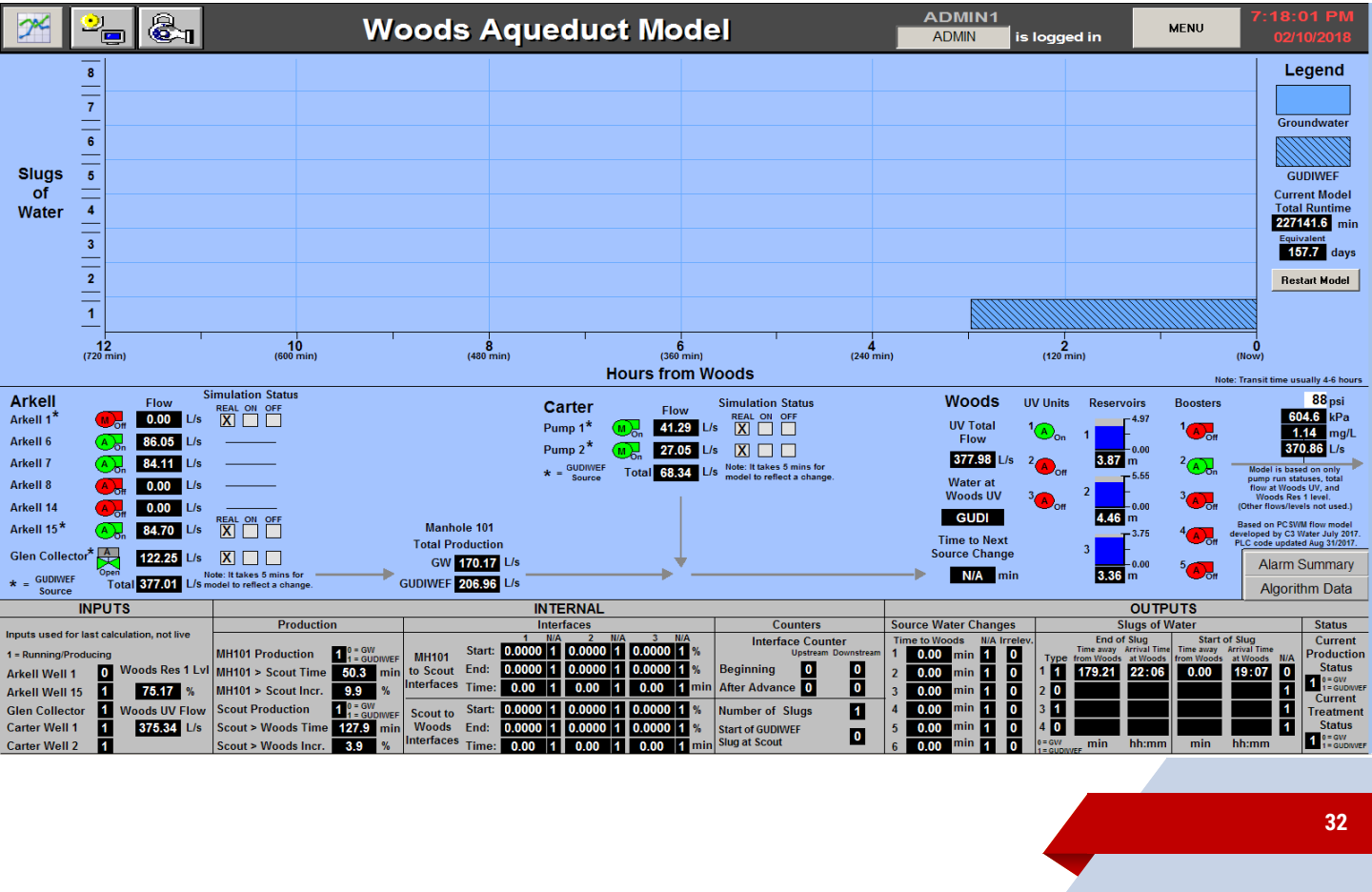
Status

Current Production Status: 1 (0 = GW, 1 = GUDI)

Current Treatment Status: 1 (0 = GW, 1 = GUDI)



Final HMI Screen for Model



INPUTS

Inputs used for last calculation, not live

1 = Running/Producing

Arkell Well 1	0	Woods Res 1 Lvl	
Arkell Well 15	1	75.17	%
Glen Collector	1	Woods UV Flow	
Carter Well 1	1	375.34	L/s
Carter Well 2	1		

Production

MH101 Production	1	0 = GW 1 = GUDIWEF	
MH101 > Scout Time	50.3	min	
MH101 > Scout Incr.	9.9	%	
Scout Production	1	0 = GW 1 = GUDIWEF	
Scout > Woods Time	127.9	min	
Scout > Woods Incr.	3.9	%	

INTERNAL

Interfaces

		1	N/A	2	N/A	3	N/A	
MH101 to Scout Interfaces	Start:	0.0000	1	0.0000	1	0.0000	1	%
	End:	0.0000	1	0.0000	1	0.0000	1	%
	Time:	0.00	1	0.00	1	0.00	1	min
Scout to Woods Interfaces	Start:	0.0000	1	0.0000	1	0.0000	1	%
	End:	0.0000	1	0.0000	1	0.0000	1	%
	Time:	0.00	1	0.00	1	0.00	1	min

Counters

Interface Counter

	Upstream	Downstream
Beginning	0	0
After Advance	0	0

Number of Slugs	1
Start of GUDIWEF Slug at Scout	0

OUTPUTS

Source Water Changes

	Time to Woods		N/A	Irrelev.
1	0.00	min	1	0
2	0.00	min	1	0
3	0.00	min	1	0
4	0.00	min	1	0
5	0.00	min	1	0
6	0.00	min	1	0

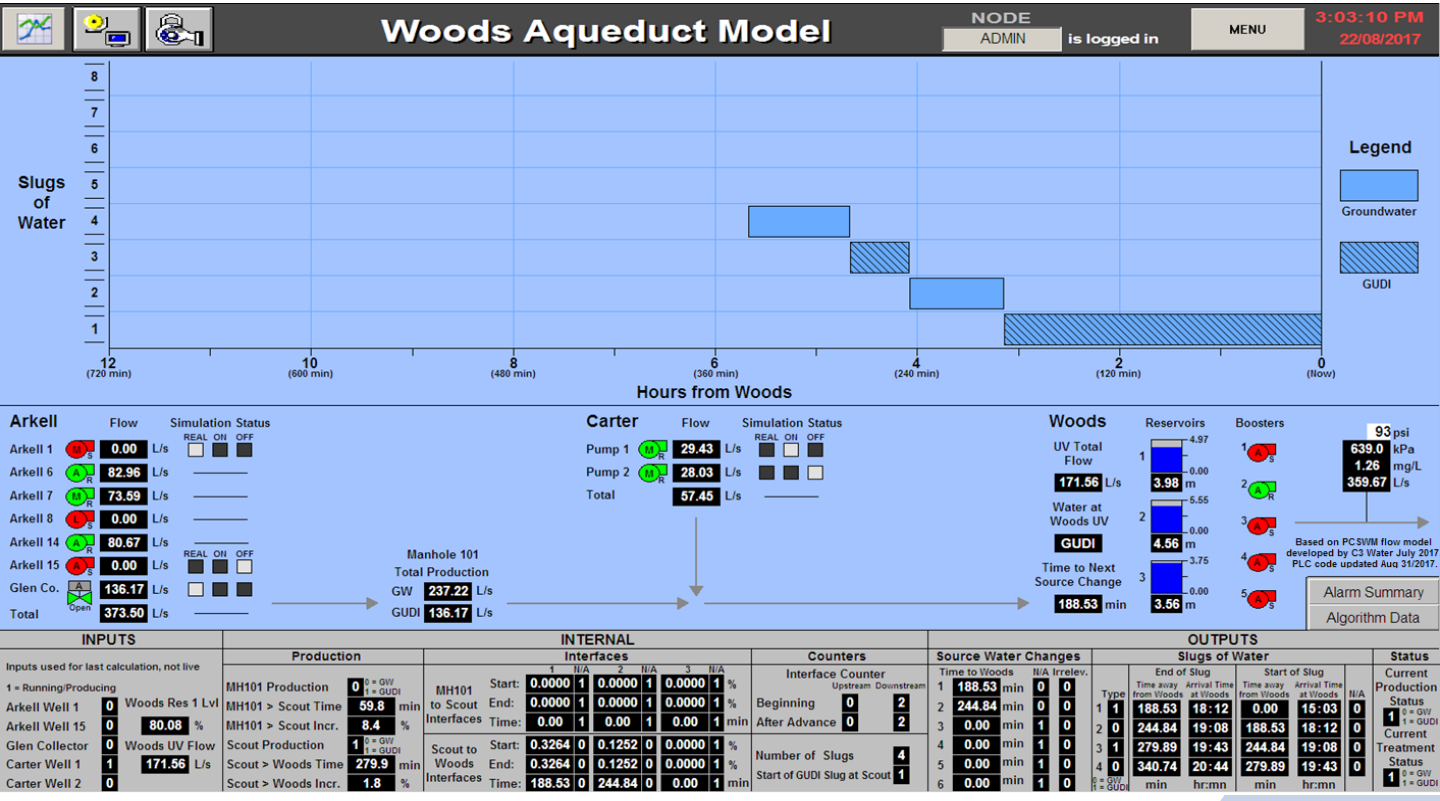
Slugs of Water

	Type	End of Slug: Time away from Woods	End of Slug: Arrival Time at Woods	Start of Slug: Time away from Woods	Start of Slug: Arrival Time at Woods	N/A
1	1	179.21	22:06	0.00	19:07	0
2	0					1
3	1					1
4	0					1
	0 = GW 1 = GUDIWEF	min	hh:mm	min	hh:mm	

Status

Current Production Status	1 (0 = GW, 1 = GUDIWEF)
Current Treatment Status	1 (0 = GW, 1 = GUDIWEF)

Final HMI Screen Design



Acknowledgements

C3 Water

- Dennis Mutti: Project Manager
- Nathan Valsangkar: Model Development

City of Guelph

- Shawn Hustins: SCADA Programming

THANK YOU!

Any questions?