Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Norfolk Gas Well Management Project

Council Meeting – April 12th, 2022

Hydrogeological Investigation Report Overview

Agenda

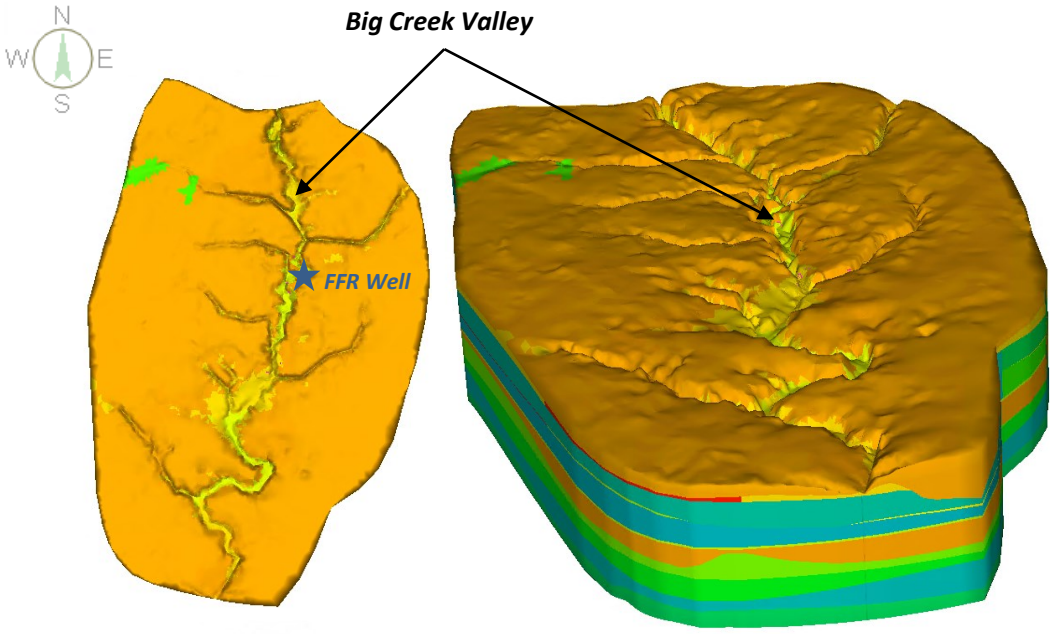
- Objectives and timeline
- Remedial options considered
- Preferred option

Objectives and Timeline

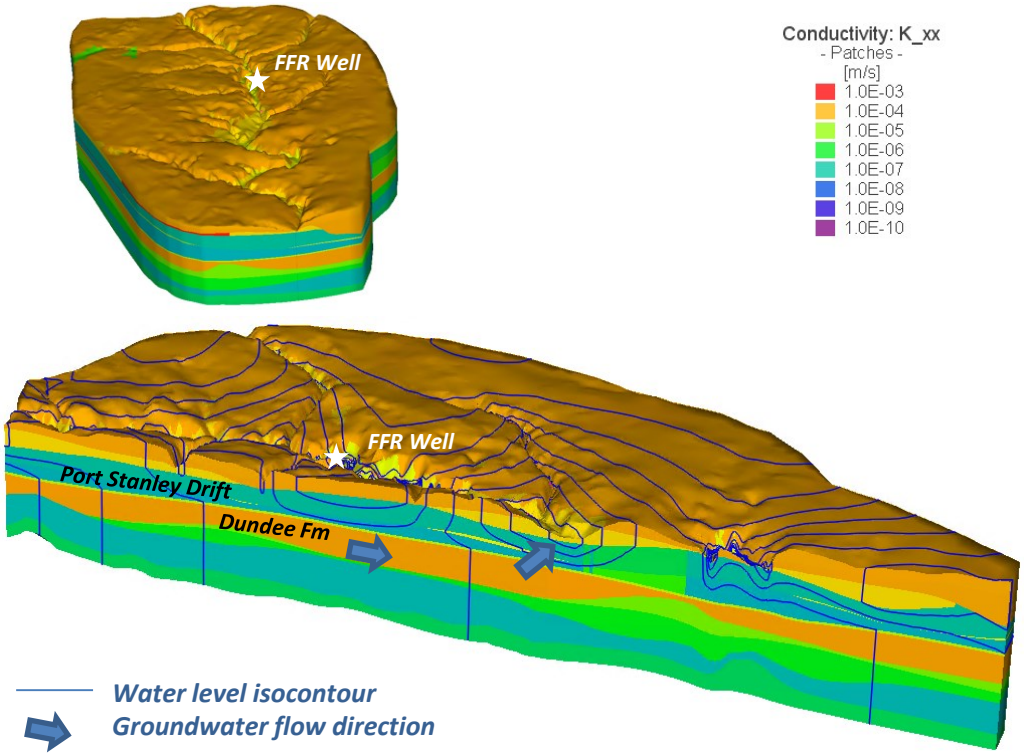
- Objectives:
  - Improve the understanding of geological and ***hydrogeological conditions resulting in flowing sulfur-rich water at oil/gas wells*** in Big Creek Valley, specifically around the Forestry Farm Road (FFR) well
  - ***Support future remedial actions***
    - assess the impacts of previous well plugging initiatives
    - allow a definition of the potential area that may be affected by flowing gas wells
    - provide a framework for assessment of remedial action(s)
- Timeline:
  - January 2021 Project initiation
  - July 2021 Presentation preliminary results to council
  - December 2021 Final report submitted
  - **April 2022 Preferred remedial option**

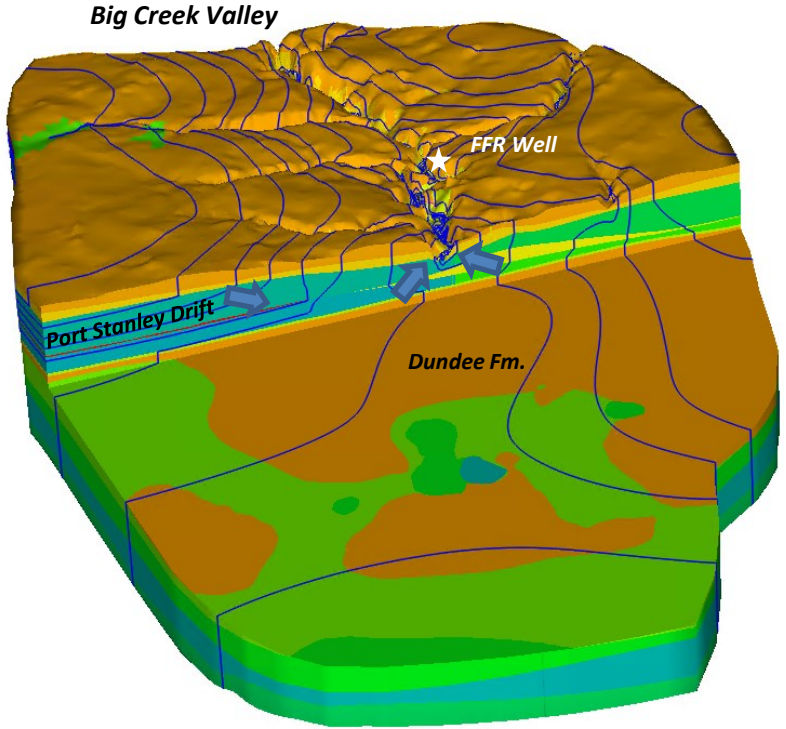
Overview of the Decision-Making Tool

- Width (EW): 12.5 km
- Length (NS): 19.4 km
- Area: 186 km^2
- Considerations:
  - Area of observed flowing wells
  - Regional flow system for overburden and bedrock
  - Surface and groundwater divides
  - Inflow from Northeast, outflow to the South
- 271 Existing Oil and Gas wells in study area



Overview of the Decision-Making Tool





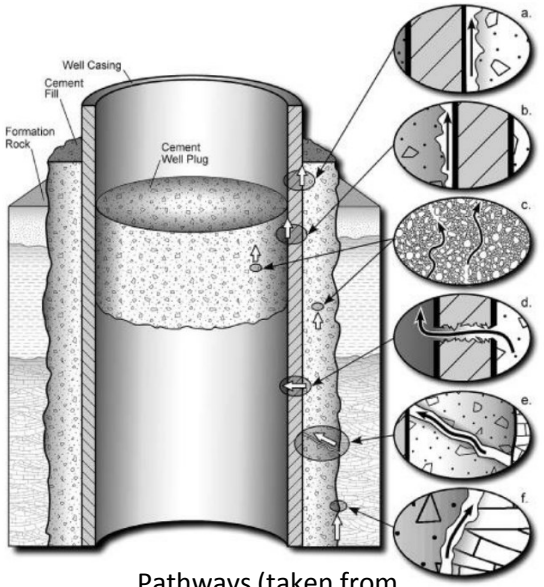
Why are there Flowing Wells?

1. Natural artesian conditions
water level in Dundee Formation is above ground surface

2. Corroded well casings and failed plugs = pathway from confined sulfur water aquifer to ground surface

Photos taken from Carter et al (2014)

Examples of sulfur water induced casing corrosion (taken from Carter 2011)



Pathways (taken from Celia et al 2004)

Ranking Future Flowing Well Potential

TABLE D Well Status in Big Creek Valley

Well Status	Within the Artesian Zone (Big Creek Valley)	Within 500 m of the Artesian Zone	Total Number of Wells
Abandoned	76	133	209
Active	14	18	32
Suspended	7	6	13
Unknown	10	14	24
TOTAL	**107**	**171**	**278**

- **Abandoned:** wells for which a plugging record is on file at the OGSR Library
- **Active:** wells currently in production
- **Suspended:** wells recently in production that are not currently producing oil or gas
- **Unknown:** wells for which it cannot be determined if plugging was or was not completed (i.e., there is no record of plugging)

Study Area
Simulated Artesian Zone Pre 1966
Water Body
Watercourse
Highway
Road
Community

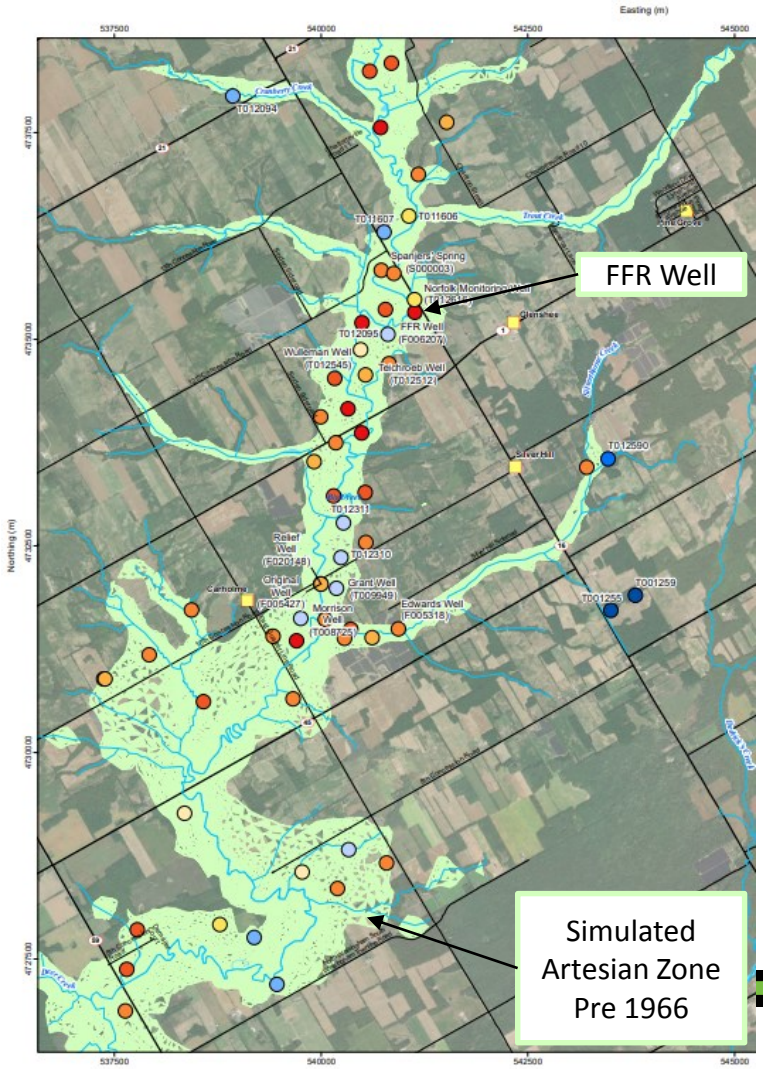
Relative Risk

0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0

Note:
Value of 1 = Highest Risk
Value of 0 = Lowest Risk

TABLE F Compromise Approach Criteria Weighting

Criteria	Weight	Lower Limit	Upper Limit	Unit
Dundee Fm. Water Level Above Ground Surface	1	-11	20	m
Plugging Event Date	1	Pre-1965	2019	year

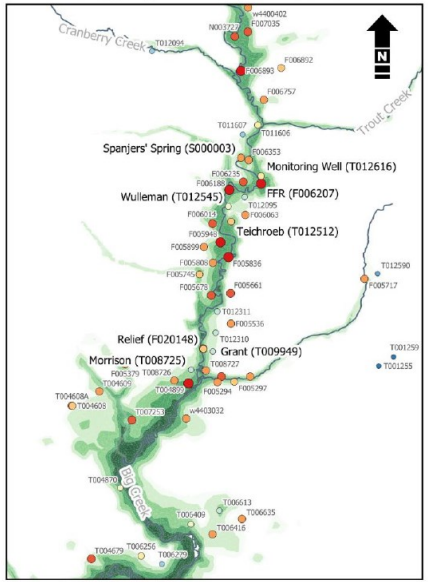


Assessment of Remedial Options

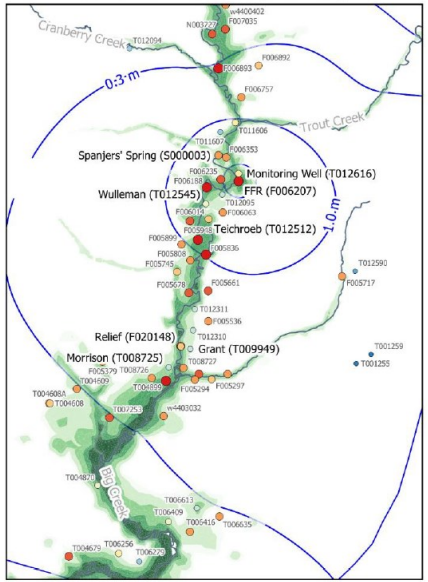
Name	Pros	Cons
Option #1 Plugging the Forestry Farm Road (FFR) Well	- Eliminates environmental concerns at FFR location - Meets requirements of *Oil, Gas and Salt Resources Act*	- Other current flowing wells not addressed - Will likely cause a pressure increase and/or flowing rates at other currently flowing wells
Option #2 FFR flow to surface capture and treatment	- Improves local air quality - Current volume is estimated to be 55 m^3/day, marginal compared to option #3 and #4	- No warranty that the flowing rate will remain at this rate in the future - Requires construction of water treatment facility - System may need upgrading if flow volume increases due to deterioration of plugs or casing - Recurring/ongoing cost for future generations
Option #3 Relief FFR C&T: Relief well near FFR capture and treatment	- Potential sub-regional solution to flowing wells	- Need to drill new well - Time and costs associated with an EA, design and construction - Recurring/ongoing cost for future generations - Regulators may still require other wells to be plugged
Option #4 Relief Original C&T: Relief well near original well capture and treatment	- Potential sub-regional solution to flowing wells	- Need to re-enter relief well or drill new well - Time and costs associated with an EA, design and construction - Recurring/ongoing cost for future generations - Regulators may still require other wells to be plugged

Remedial Options: Spatial Influence

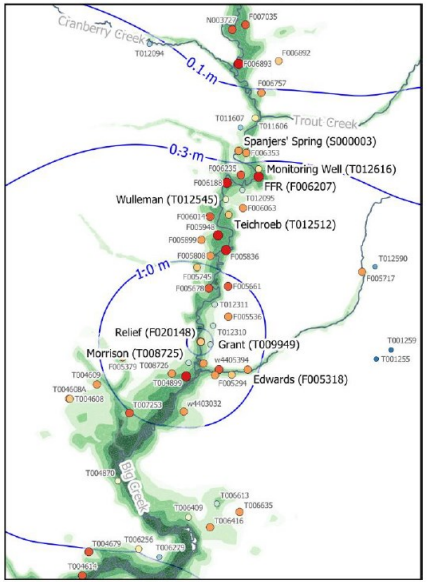
Option 1 & 2:
Plugging FFR or Capture & Treat



Option 3:
Relief Well Near FFR (F006207)



Option 4:
Relief Well Near Original (F005427)



Legend
- Surface Water Features
- Simulated Change in Water Level (m)

Simulated Artesian Zone (m)
- 0.0 - 0.0
- 0.0 - 4.0
- 4.0 - 10.0
- 10.0 - 16.0
- 16.0 - 22.0

Relative Risk (Highest = 1.0)
- 0.01 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.60
- 0.60 - 0.70
- 0.70 - 0.80
- 0.80 - 0.90
- 0.90 - 0.99

- Predicted 0.3m increase in water levels within 10m radius of FFR well

- Assumed flowing rate of **55 m^3/day***

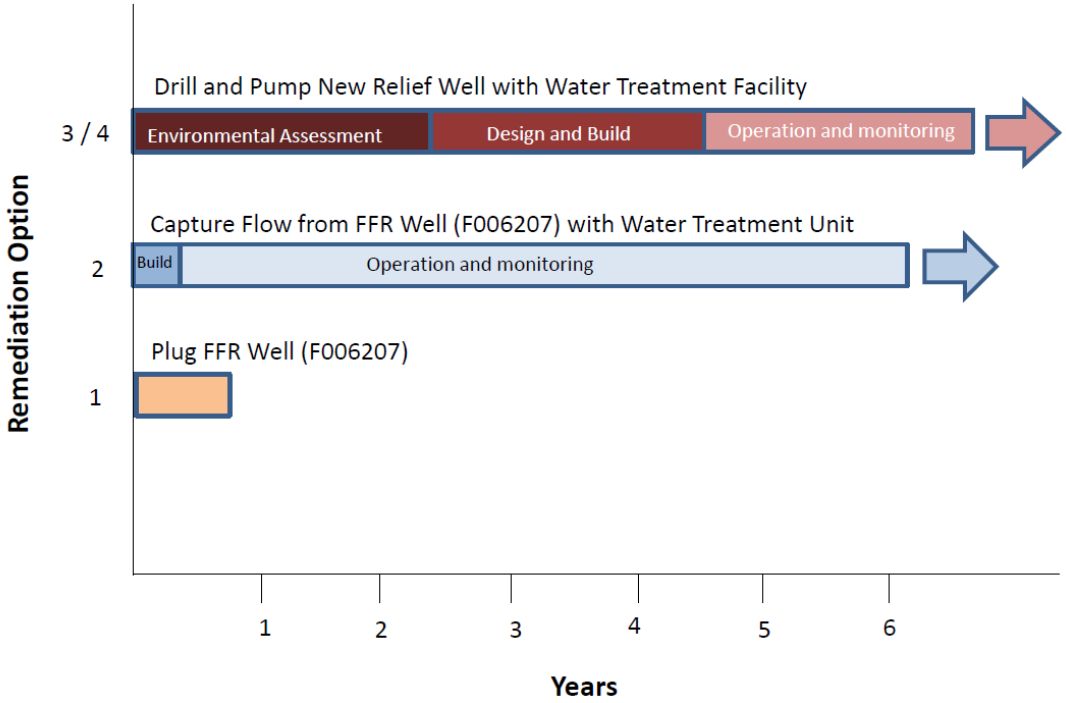
- Options 3 and 4: have the **most impacts regionally**

- Between **10 and 14 wells** within the 1 m change in water levels radius (1.7 km)

- Predicted well capacity in the order of **3,800 m^3/day**.

Note: **Norfolk County monitoring well encountered flowing rate up to **1,100 m^3/day***

Remedial Options: Time and Cost



	Cost	
	Capital	Ongoing
3 / 4	$$$$$	$$$$$
2	$	$$$$
1	$$	N/A

*Capital cost and ongoing cost **multi-millions** of dollars.*
Formal cost estimate was not part of this scope of work.

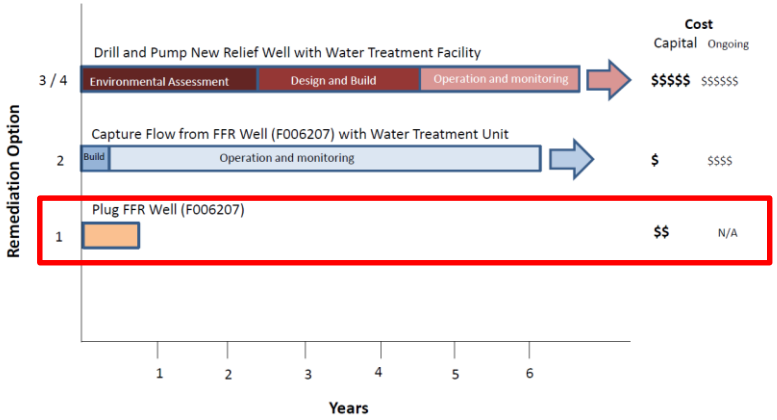
*Capital cost: less than **$500,000***
***Ongoing cost** until a different remedial option is implemented.*

*Capital cost: **$500,000 to $750,000***
***No ongoing cost** once plugged.*

Preferred Option

Name	Pros	Cons
Option #1 Plugging the Forestry Farm Road (FFR) Well	- Eliminates environmental concerns at FFR location - Meets requirements of *Oil, Gas and Salt Resources Act*	- Other current flowing wells not addressed - Will likely cause a pressure increase and/or flowing rates at other currently flowing wells

Identified as the best long-term solution.



Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF)- Communication

- This study was conducted following a request from NDMNRF
- Norfolk County communicated results from this study to NDMNRF
- Norfolk County received confirmation that NDMNRF will be covering all the costs associated to the well abandonment, through the Abandoned Works Program funds (Abandoned Works Program | ontario.ca)

No cost to Norfolk County