Environmental Impact and Risk Assessment

Simulation of Contaminant Plume Migration in Sub-surface

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Literature Review

- Groundwater contamination is a global issue and is challenging (Swartjes, 2011).
- Difficult to detect the sub-surface contamination at earlier stages and even in case of detection, can take up to several years for remedy.
- Several analytical and numerical models have been developed to characterize the plume flow.
- Use of 1-D and 2-D analytical models to quantify contaminant discharge and delineate plume flow (Wilson et al., 1978 , Memarianfard et al., 2015, Chen et al., 2016).
- Environmental impact and risk assessment considered as one of the most significant approach to limit further groundwater contamination.
- Environmental impact and risk assessment in potential contaminant sites (Popita et al., 2014, Wijesekara et al., 2014).
- Despite of tremendous works in groundwater contamination, very few of the literatures have tried to capture the uncertainty in contaminant fate and transport.

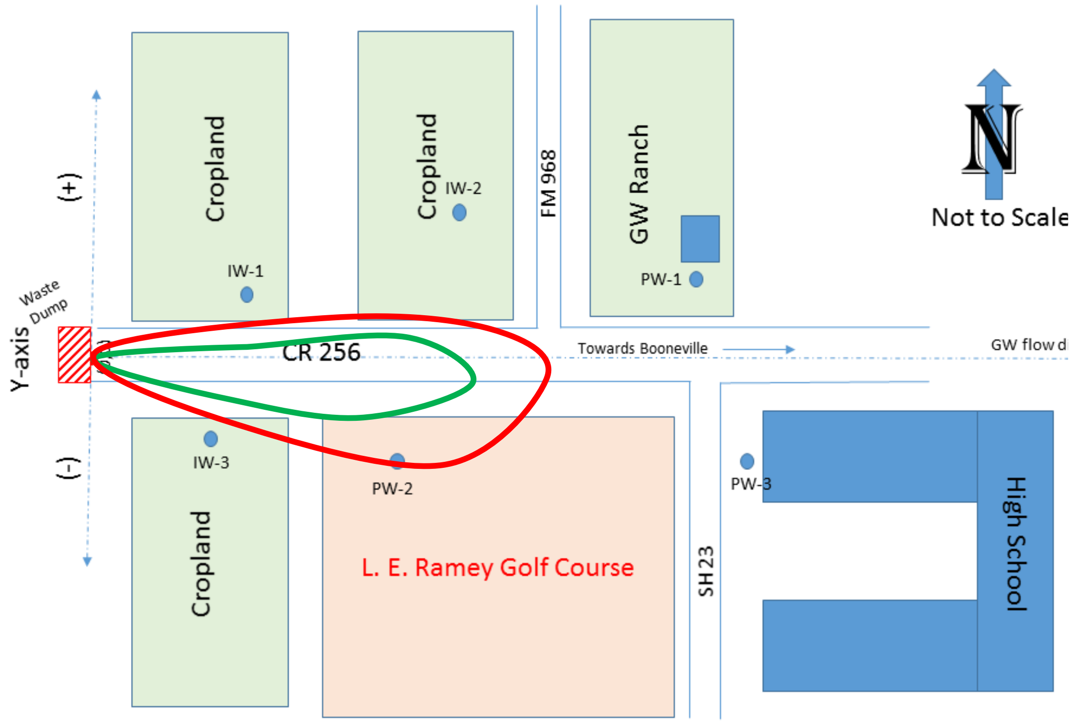
Motivation (Why)

- Increasing number of Contaminated sites.
- Increasing reliance on groundwater sources.
- Sub-surface contamination is highly problematic-
  - Difficult to detect unless some serious case is observed
  - Might take several years to remove once detected
- Early assessment of risks helps to avoid most of the potential future contaminations.
- Limit physical, financial and regulatory risk thus saves economy and health of people in a long run.

Objective (What)

- Use of analytical solution to characterize the plume flow (Wilson et al., 1978) in proposed landfill site.
- Use of probability analysis software NESSUS for design so as to incorporate uncertainty associated with input parameters.
- Develop more reliable and robust model.
- Graphical visualization of the results.
- Decision making process through impact and risk assessment.

Research Problem and Assumptions



Parameter	Value	Reference
V (m/d)	1.0	Velocity
η	0.35	Porosity
D_x **(m²/d)**	5.0	Dispersion along X- Direction
D_y **(m²/d)**	1.0	Dispersion along Y- Direction
R	1.3	Retardation factor
$t_{0.5}$	180	Half-life of contaminant
Q (m^3/d/m)	1.0	Mass leaching rate
C_0 (g/m^3)	50.0	Initial concentration at (x, y) = (0,0)
MCL(g/m^3)	1/1.5	Maximum Contaminant Level (Municipal/Irrigation)
P_O	$10^{-4}/10^{-3}$	Target Probability (Municipal/Irrigation)

Deterministic Analysis

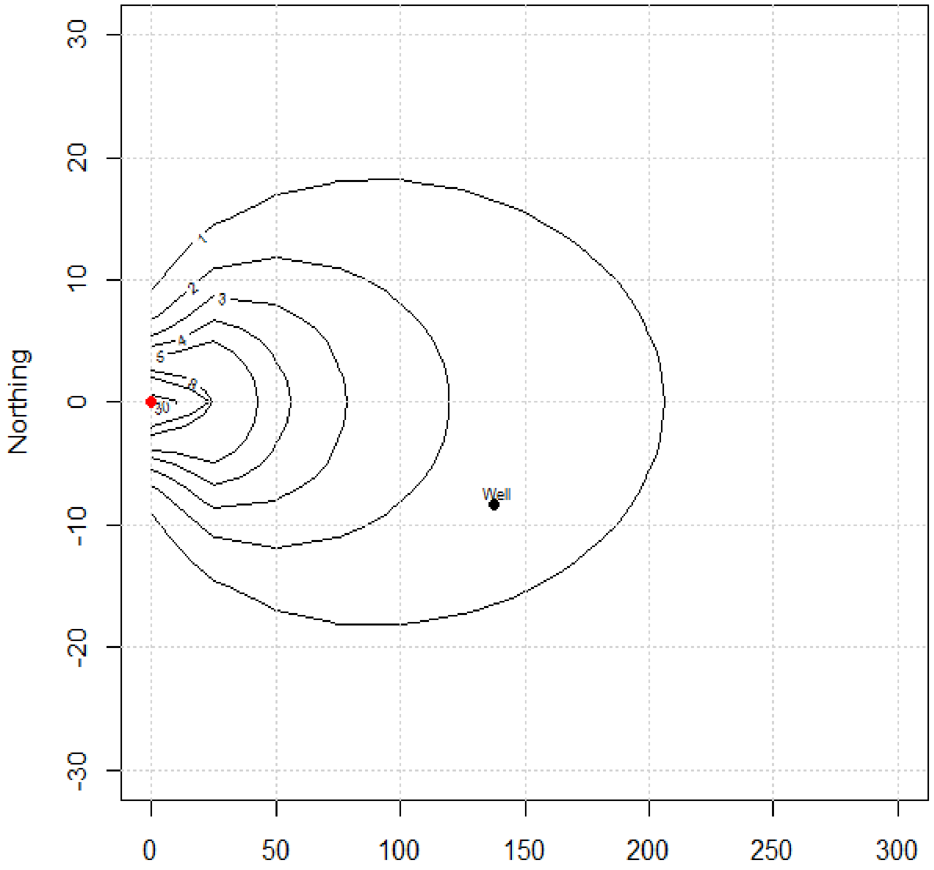
- All the parameters are assumed to be a deterministic value and concentration at the water source (C) is calculated (Wilson and Miller,1978):

$$C = \frac{Co * Q}{2 * \pi * \eta * \sqrt{D_x D_y}} * \exp\left(\frac{V * x}{2 D_x}\right) * Ko(B)$$

$$C = 0.0294 * Co = 0.0294 * 50$$

$$= 1.47 \text{ g/m}^3 \ (>1 \text{ g/m}^3)$$

- The concentration at the water source exceeds the Maximum Contaminant Level (MCL = 1 g/m^3), incase of contaminant leachate from the proposed site.
- The landfill site has a potential threat to the city.
- Project is Unsafe for municipal use.
- However, can be Safe if the well is used for irrigation purpose only.



Probabilistic Analysis and NESSUS

- Parameters are treated as Random Variable and not deterministic.
- For simplicity, parameters except initial concentration are still assumed to be deterministic which may not be the case.
- To account for lack of data, we shall run the analysis for different distribution and parameters and analyze the results.
- Probability of failure (for municipal use shown here) is obtained as:

$$P_f = P(g(X) \leq 0)$$

where,

$$g(X) = MCL - C$$

Response Function
(g - Function)

$$g(X) = 1 - 0.0294 * Co$$

Results and Discussion

Same Distribution, Different Parameters

- Lognormal Distribution
  - Mean: 75%, 50% and 25% of deterministic value (50)
  - S.D: 10% around mean
- Analysis is sensitive to parameters estimation.

Distribution (Lognormal)	Mean	S.D	Probability of Failure (P_f)	Municipal ($P_O=10^{-4}$)	Irrigation ($P_o=10^{-3}$)
Minimal Risk	37.5	3.75	0.823	Unsafe	Unsafe
Moderate	25	2.5	$0.85*10^{-3}$	Unsafe	Acceptable
Elevated Risk	12.5	1.25	~0	Safe	Safe

Same Parameters, Different Distribution

- Mean: 50% of deterministic value and S.D of 10% around the mean
  - Lognormal, Normal, Weibull
- Analysis is sensitive to parameter distribution.

Scenario (Moderate)	Mean	S.D	Probability of Failure (P_f)	Municipal ($P_O=10^{-4}$)	Irrigation ($P_o=10^{-3}$)
Lognormal	25	2.5	$0.85*10^{-3}$	Unsafe	Acceptable
Normal	25	2.5	$0.15*10^{-3}$	Unsafe	Safe
Weibull	25	2.5	$0.1*10^{-10}$	Safe	Safe

Conclusion

- Groundwater contamination is challenging due to multiple sources of contamination and complex sub-surface interactions.
- Environmental impact and risk assessment could be one of the best solution to limit the contamination problems.
- Analytical solution was used to study the plume characteristics at the proposed landfill site.
- Deterministic solution suggest potential threats whereas probabilistic analysis using NESSUS gave different results corresponding to different distributions.
- Appropriate selection of the distribution and best estimates of distribution parameters is required for reliable results for decision making.
- Probabilistic software such as NESSUS can be useful in solving complex analysis.
- Analysis based on single deterministic value is not recommended for decision making process unless we are sure on the variability and uncertainty.