

Gelman Site 1,4-Dioxane Groundwater Contamination Plume Modeling and Prediction

Presenter: Yifan Luo, MS (ESM, GDS)

Advisors: Dr. Drew Gronewold, Dr. Derek Van Berkel

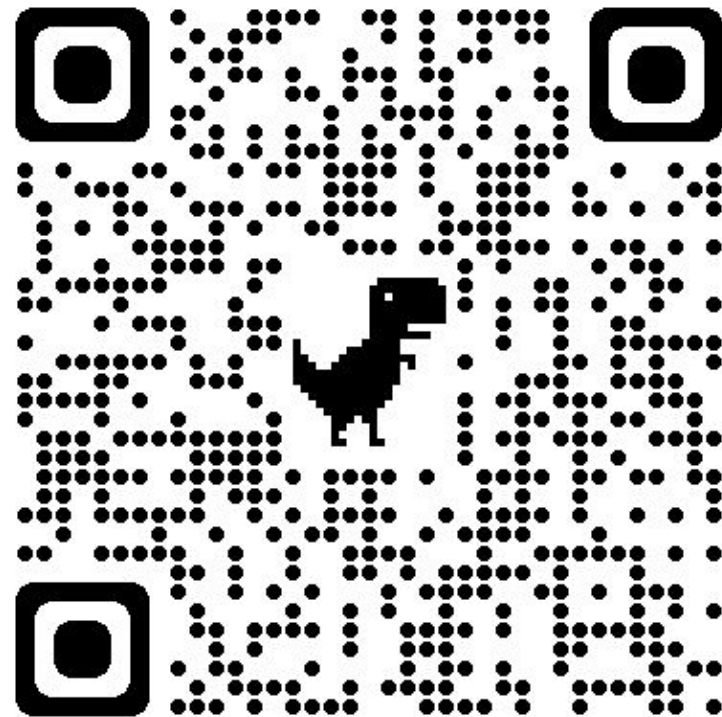
Client: Scio Township, MI

Date: April 15, 2022



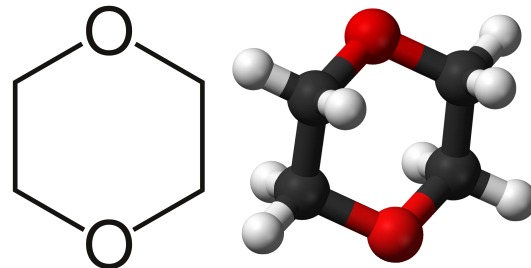
Interactive Web Application

*Please wait for the map to load before proceeding, it will take a few seconds.



http://50.17.61.223:3838/gelman_shiny/

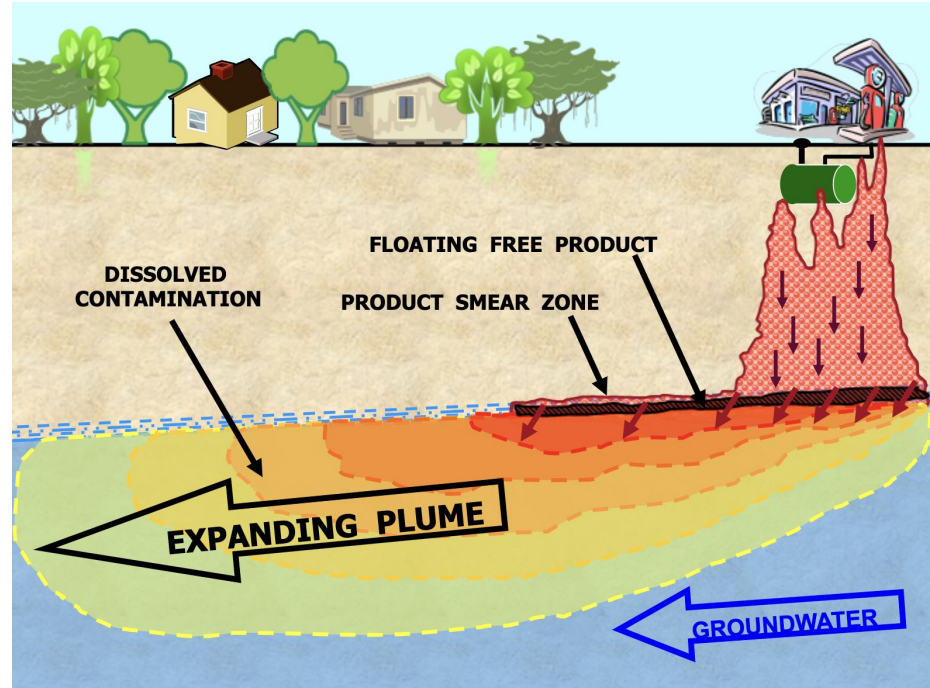
What is 1,4-dioxane?



- Group 2B Carcinogen: **Possibly carcinogenic** to humans
- Chronic Effects: Possible damage to **liver and kidneys**
- Commonly found in consumer products
- **Easily dissolved** and **highly mobile** in water
- Does **not readily biodegrade** in the environment

What is a plume?

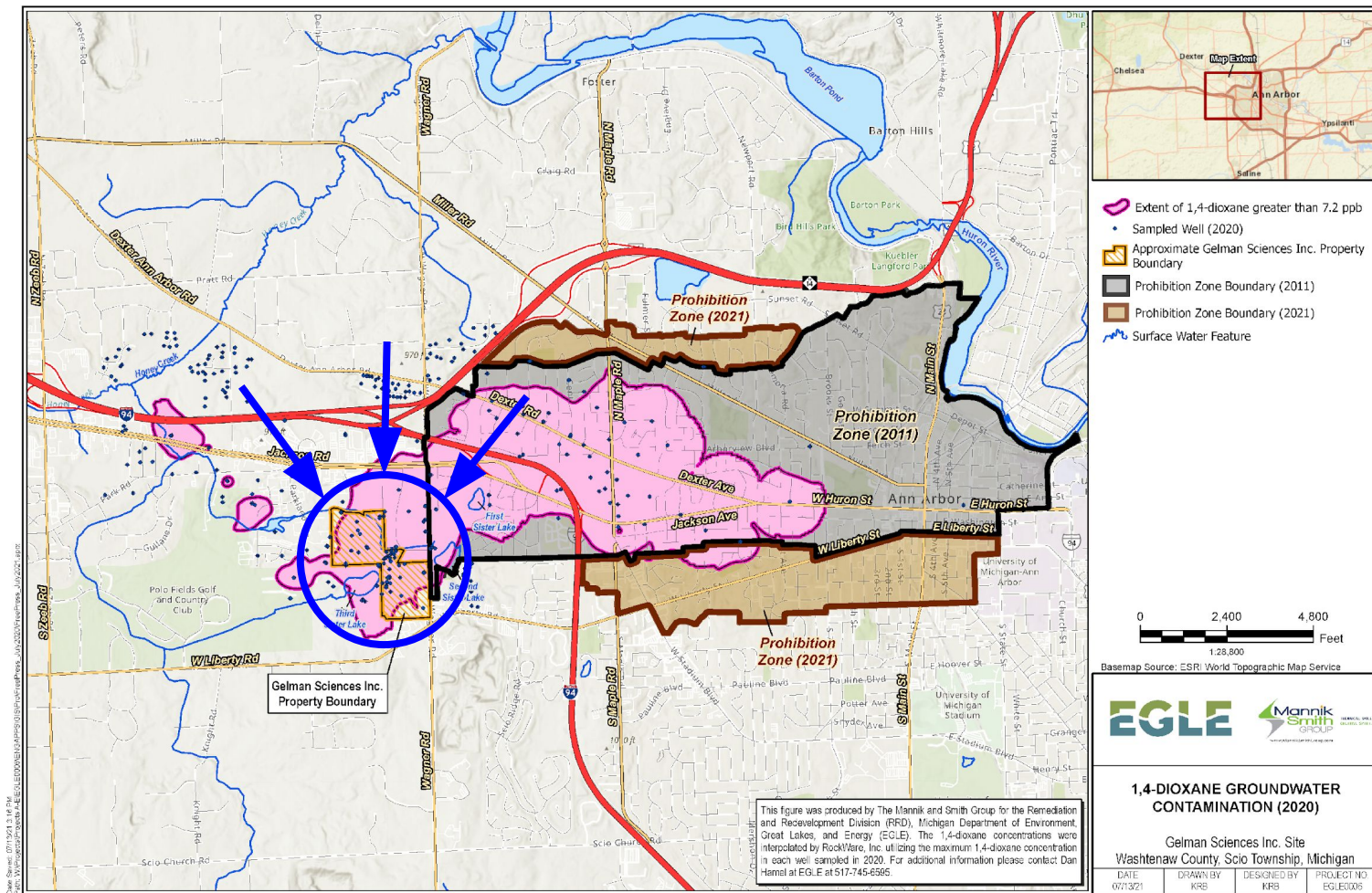
- A plume is a volume of contamination in soil or water that extends **downward and outward** from a source.
- In our project, the chemical 1,4-dioxane is moving through **groundwater**.
- Problem: wells draw groundwater for use in homes and businesses in this area.



Background

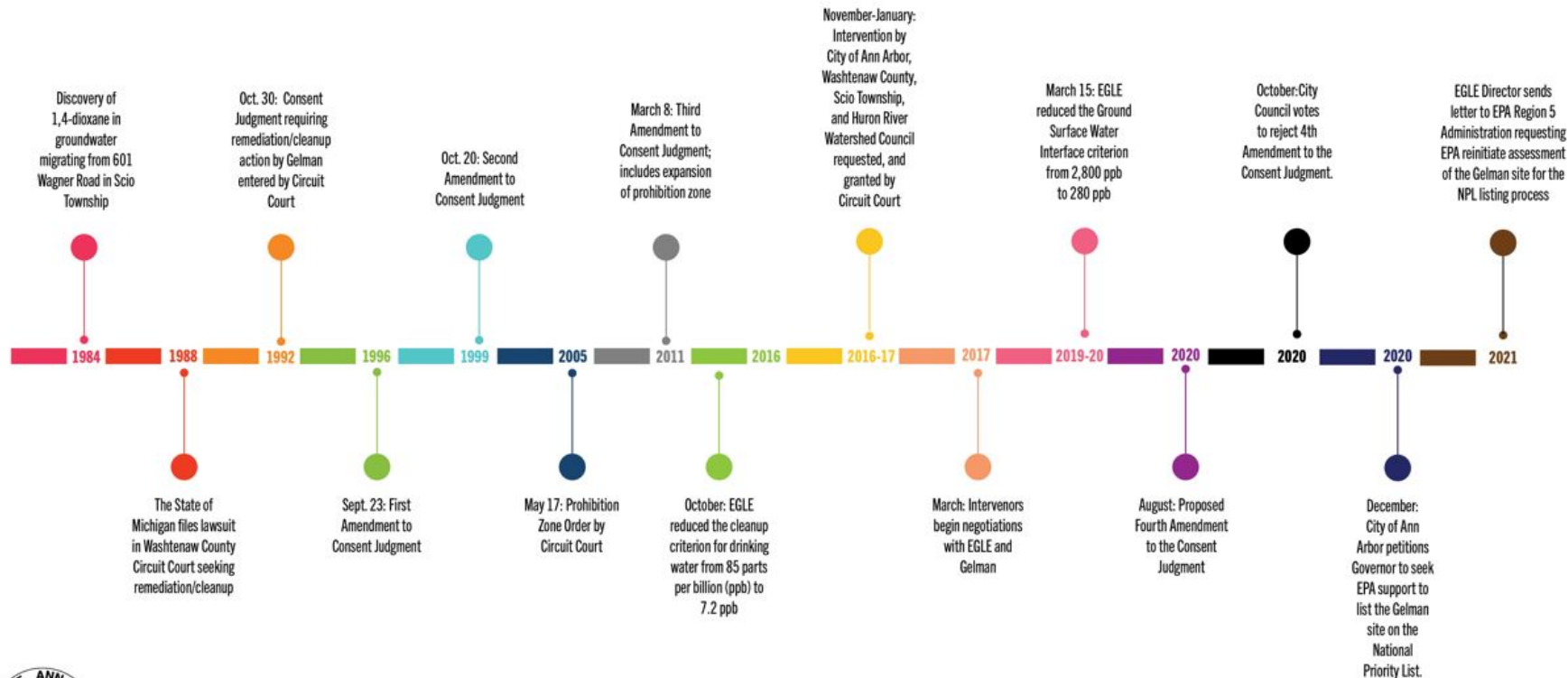
- Between 1966-1986, Gelman Sciences (now Pall Life Sciences) used 1,4-dioxane in their filter manufacturing process, and disposed of wastewater onsite.
- Since then, the plume has continued to **migrate** through the city and county, contaminating local lakes and private drinking water wells.





The depth to 1,4-Dioxane contamination in groundwater is variable throughout the plume and the depth to contamination is not represented on this 2D plume map.

Historic Timeline of the Gelman Dioxane Plume Cleanup



Last updated: April 2021

<https://www.a2gov.org/departments/water-treatment/PublishingImages/Pages/Gelman-1,4-Dioxane-Litigation/UpdatedGelmanTimeline0421.j>

1,4-Dioxane Residential Cleanup Criteria

State of Michigan's residential cleanup criteria for 1,4-dioxane:

- 3 ppb until 1995.
- In 1995 it was increased to 77 ppb.
- In 2000 it was increased again to 85 ppb.
- In 2016 it was changed to 7.2 ppb (based on EPA IRIS data from 2010) via a temporary Emergency Order that became final in 2017.

EPA does not have a promulgated drinking water standard for 1,4-dioxane:

- EPA acceptable drinking water risk range is 0.35 ppb to 35 ppb.

Consent Judgment & Legal Action

The Consent Judgment is a legal agreement between EGLE (formerly DEQ) and Gelman that dictates the monitoring and treatment of the contamination.

- October 1992: Consent Judgment (CJ) first enacted
- September 1996: 1st Amendment to CJ
- October 1999: 2nd Amendment to CJ
- July 2000: Consent Remediation and Enforcement Order
- December 2004: Opinion and Order Regarding Remediation of the Contamination of the Unit E Aquifer aka UnitE Order
- May 2005: Order Prohibiting Groundwater Use
- March 2011: 3rd Amendment to CJ
- November 2016: Ann Arbor Township, Scio Township and the Sierra Club petitioned the USEPA to perform a preliminary assessment to designate the site a federal USEPA Superfund Site.
- December 2016: Washtenaw County, Scio Township, the City of Ann Arbor and the Huron River Watershed Council joined EGLE in the lawsuit against Gelman to amend the Consent Judgment a fourth time.

Current Pumping & Treatment

- Gelman has been pumping and treating groundwater contaminated with dioxane it released since the early 1990's
- Discharges the treated water into Honey Creek which is a tributary of the Huron River
- Extraction wells are used to draw contaminated groundwater to the surface for treatment.
- 300 gallon per minute treatment required in Consent Judgment.
- The contaminated water is treated at the Gelman property using an Ozone/Hydrogen Peroxide (O_3/H_2O_2) Advanced Oxidation Process.

Primary Community Concerns

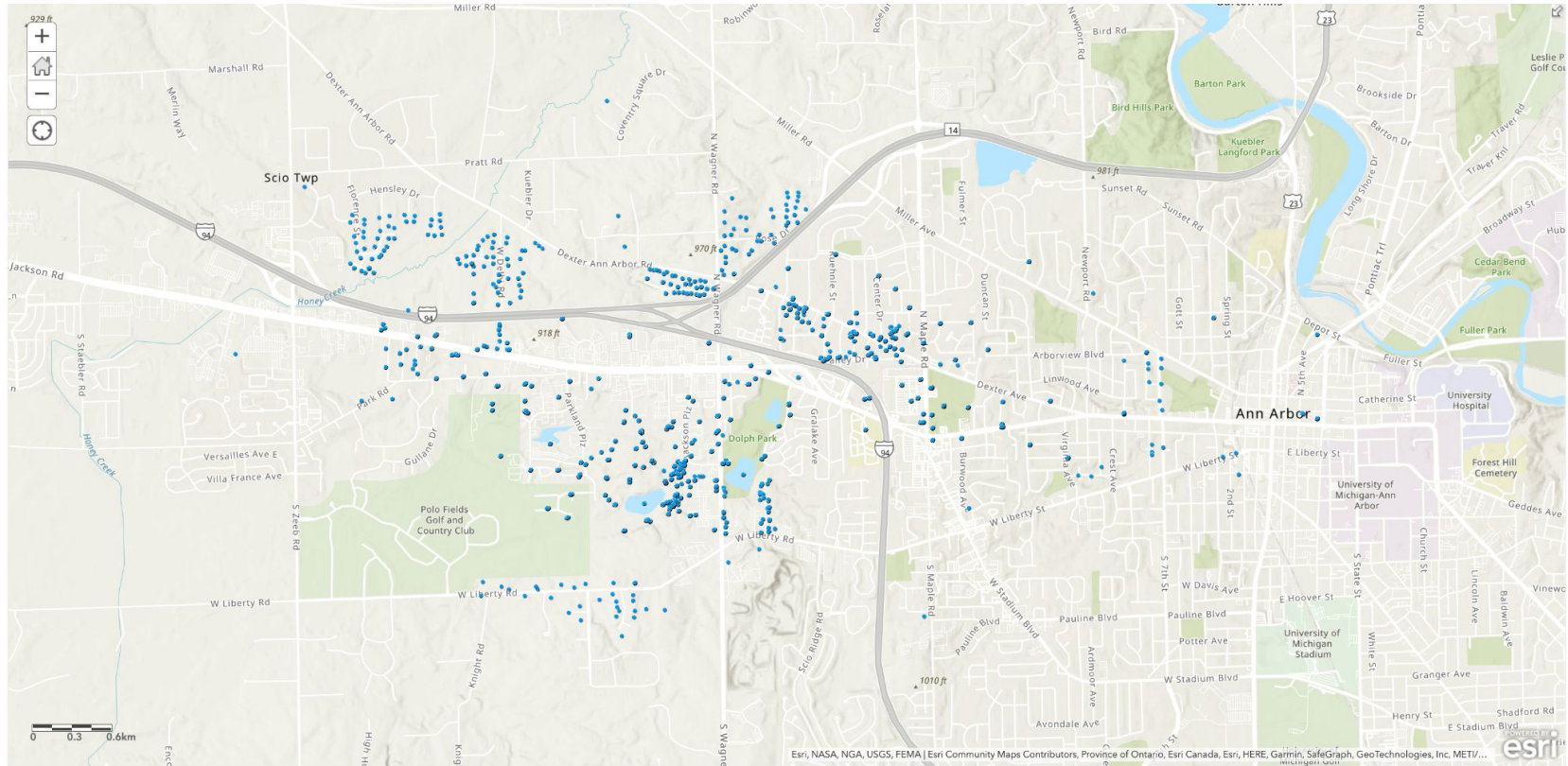
- Contamination of private drinking water wells.
- Contamination of Ann Arbor City water supply (Barton Pond).
- Contamination of Honey Creek and the Huron River.
- Exposure via shallow groundwater.

Groundwater Plume Modeling and Prediction

To provide an in-depth understanding of contamination level and its spatial-temporal distribution:

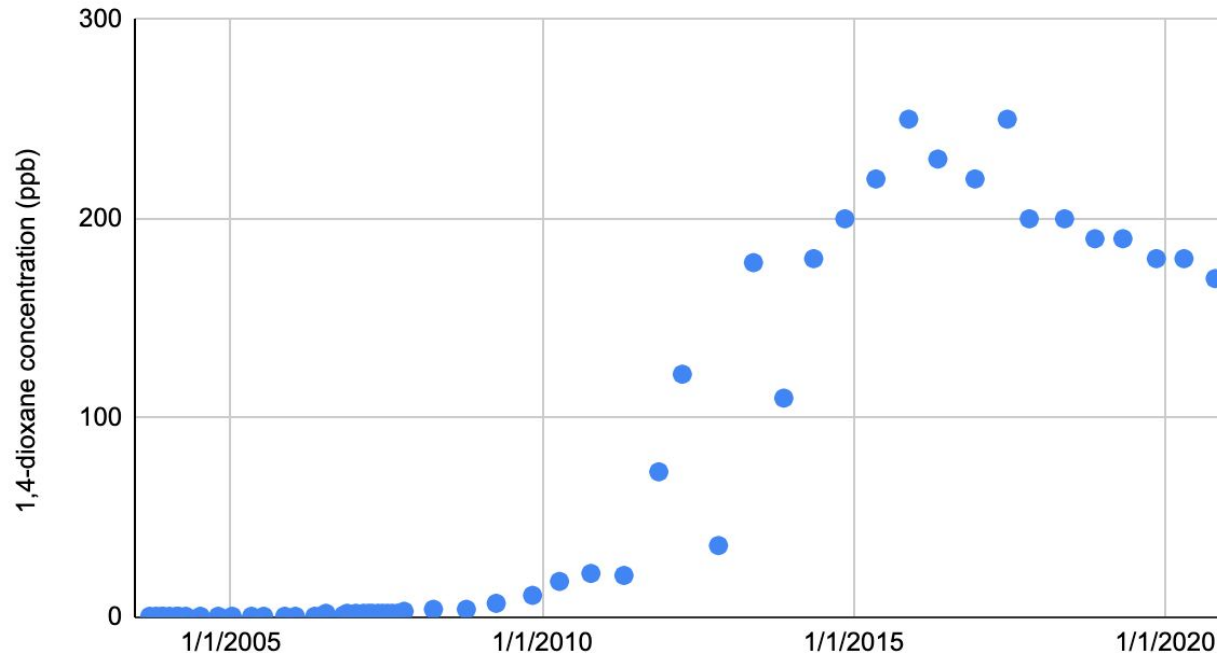
- Analyze the previous and present 1,4-dioxane pollution level of groundwater, to identify the areas that need additional attention
- Forecast groundwater quality safety and provide decision support for the administrators of drinking water safety, water environment protection, and emergency response

Challenge #1: Limited Spatial Distribution



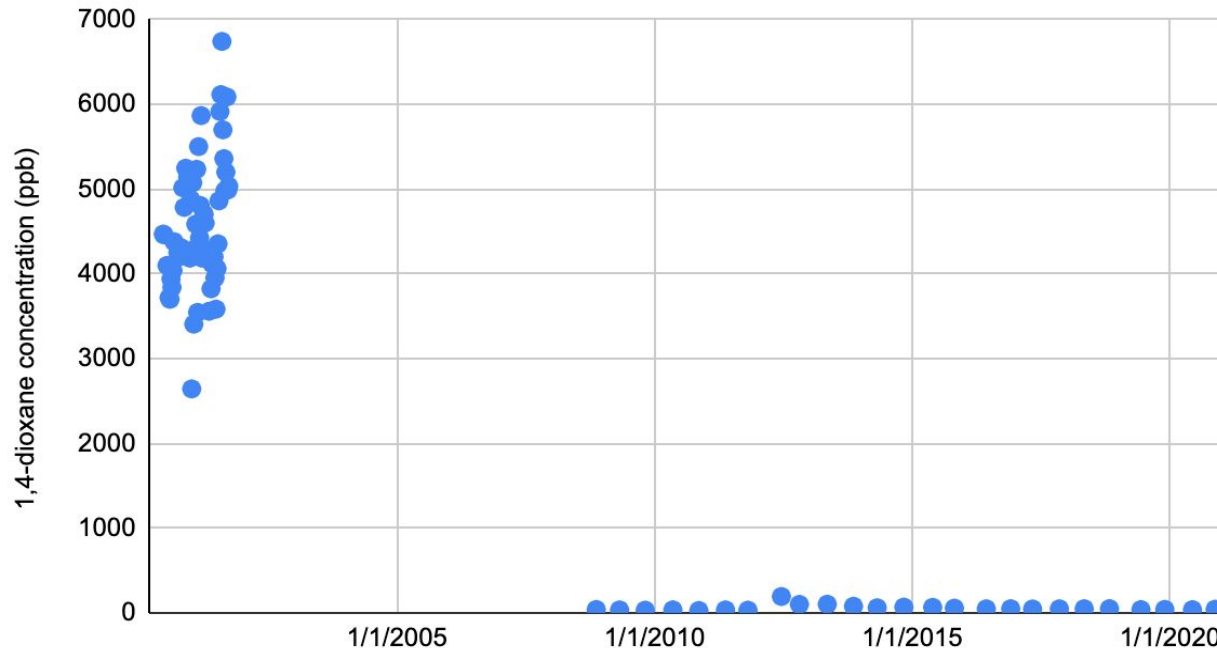
Challenge #2: Irregular and Infrequent Sampling Intervals

MW-91 Historical Record



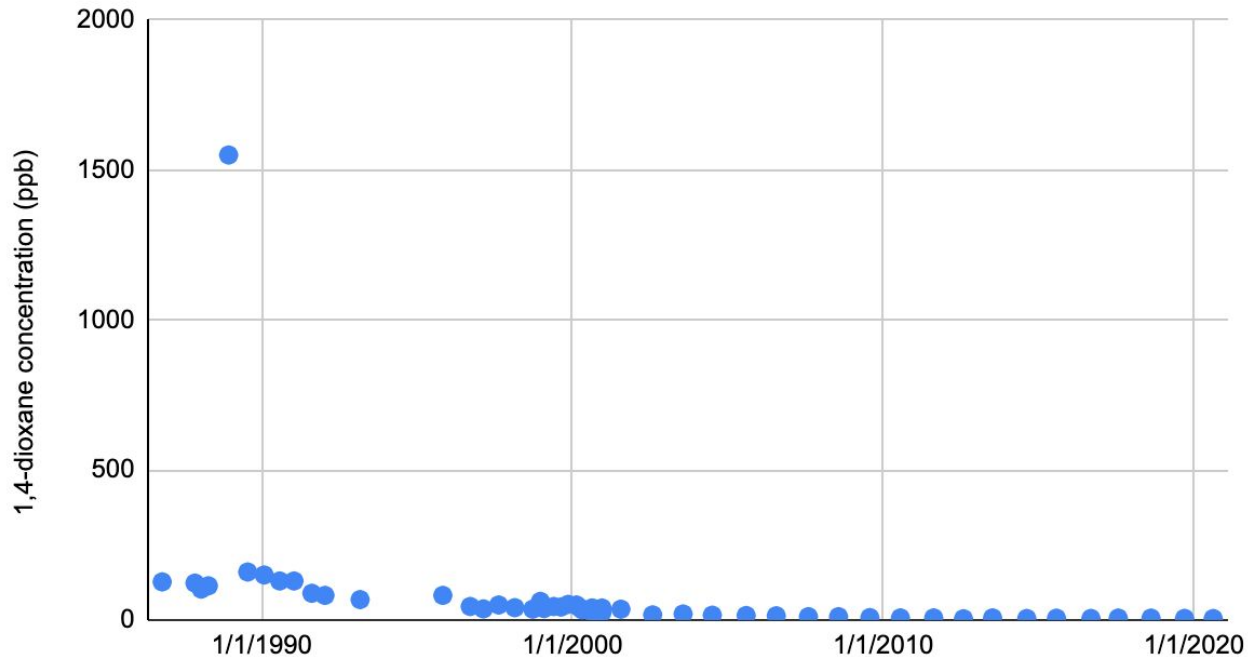
Challenge #2: Irregular and Infrequent Sampling Intervals

TW-4 Historical Record

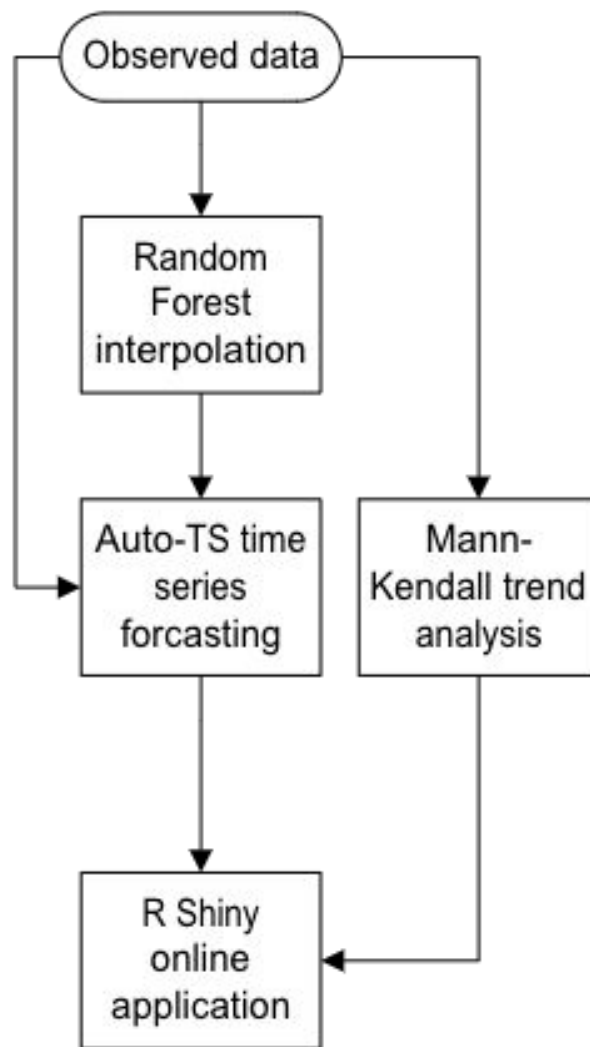


Challenge #2: Irregular and Infrequent Sampling Intervals

4401 Park West Historical Record

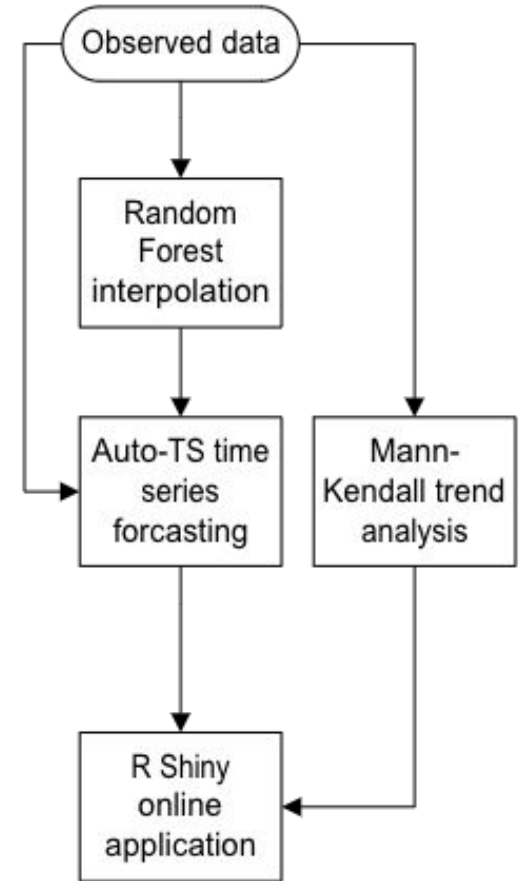


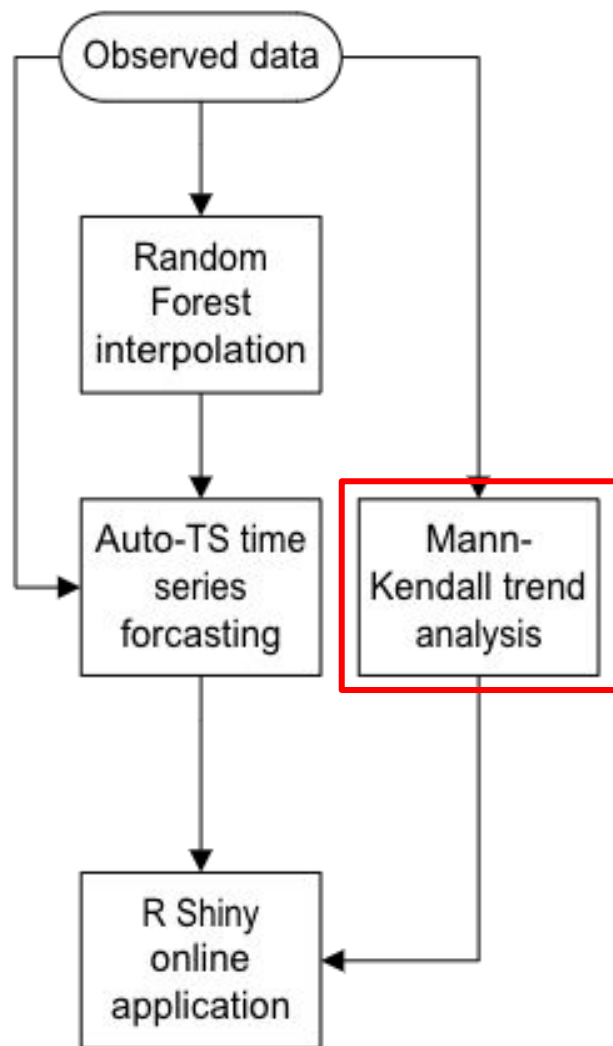
Method



Methodology Flowchart

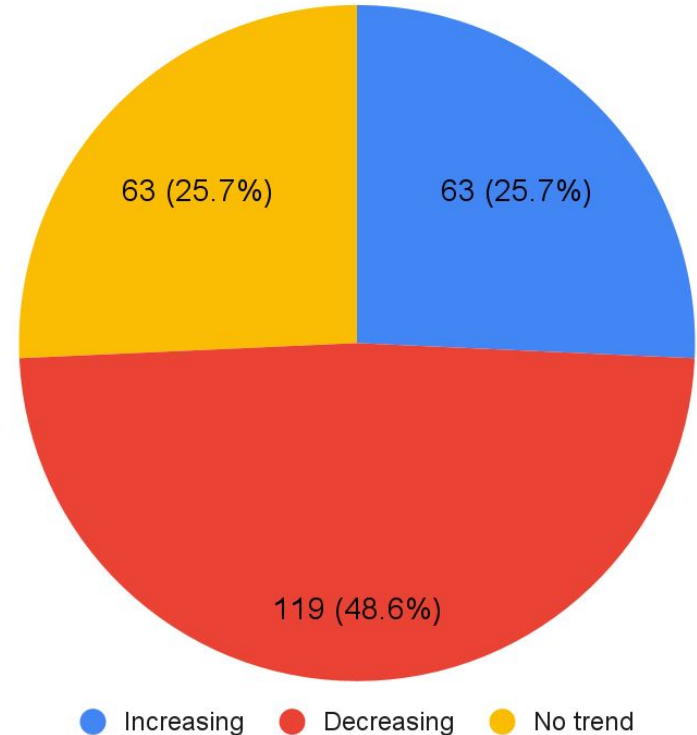
- Applied Mann Kendall test to **evaluate the trend** of dioxane concentrations at various wells.
- Developed a Random Forest model to **fill in or extend** fragmented temporal and spatial data gaps.
- Utilized a automated time series machine learning (AutoTS) package to **predict best forecasts** future values.
- Built R-based Shiny web application to allow **visualization and quantification** of analytical data.

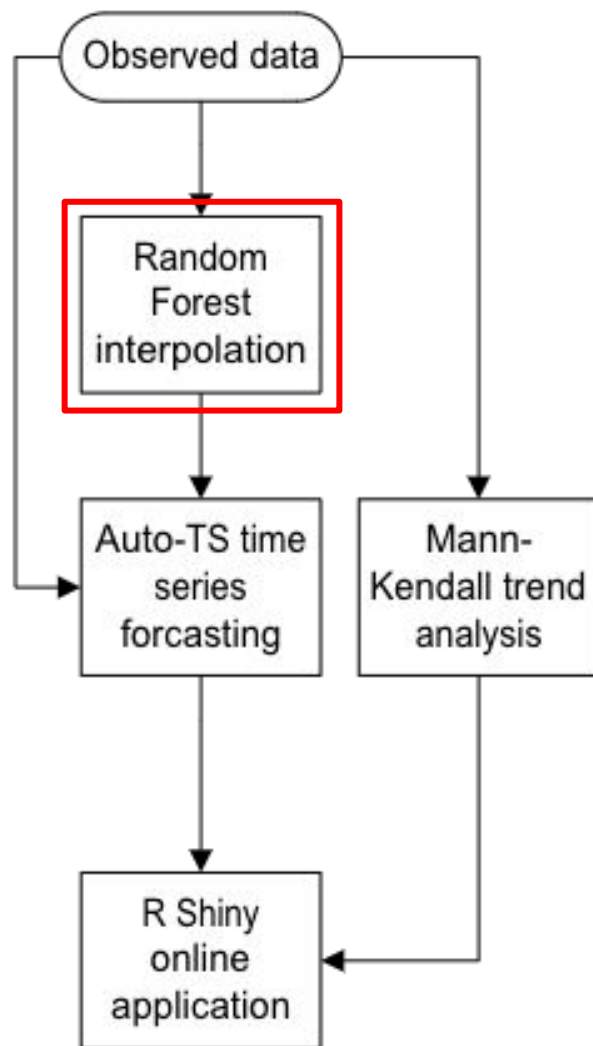




Mann-Kendall Trend Analysis

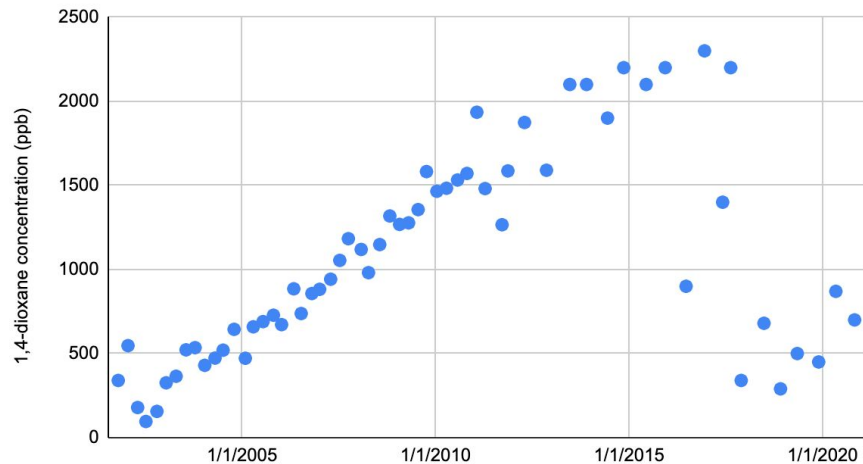
- Out of 245 sampling wells, almost half of them (48.6%) showed **decreasing** trends.
- More than a quarter (25.7%) exhibited primarily **increasing** trends.
- The other 63 wells (25.7%) showed **no significant trend**.



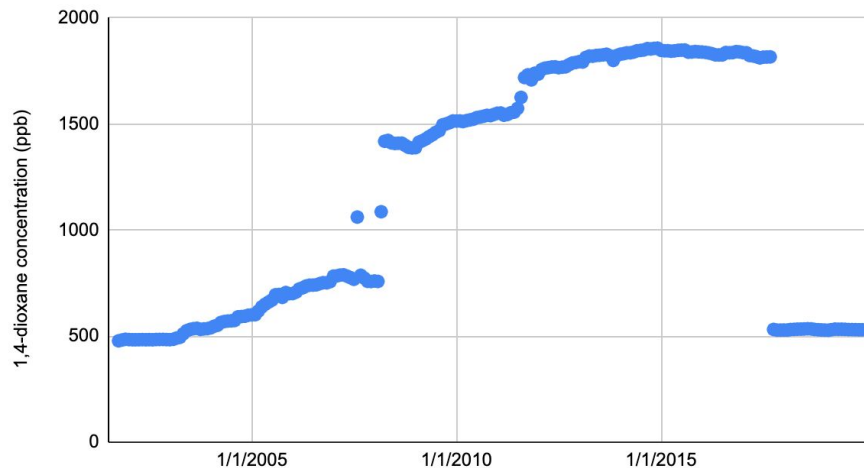


Random Forest Interpolation

MW-71 Historical Record

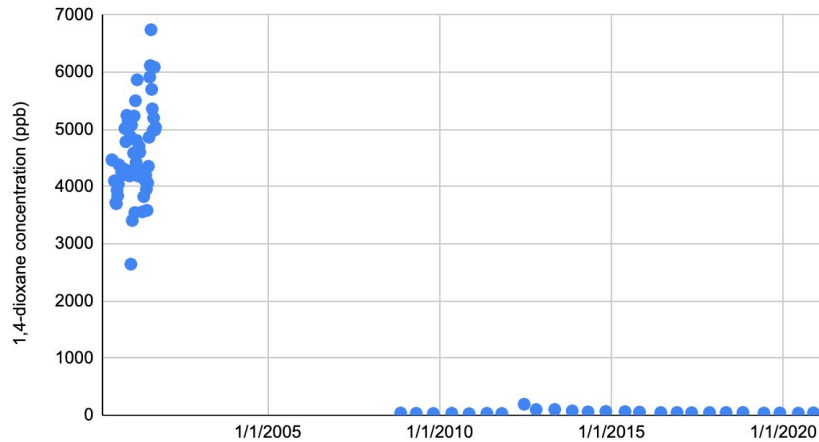


MW-71 Random Forest Interpolation

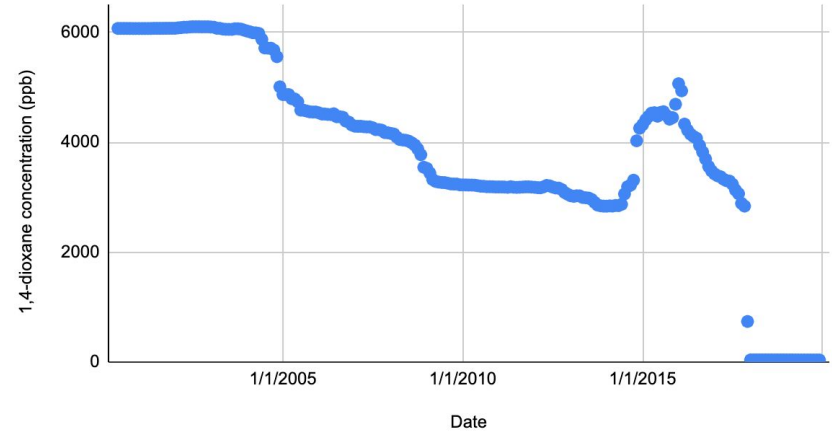


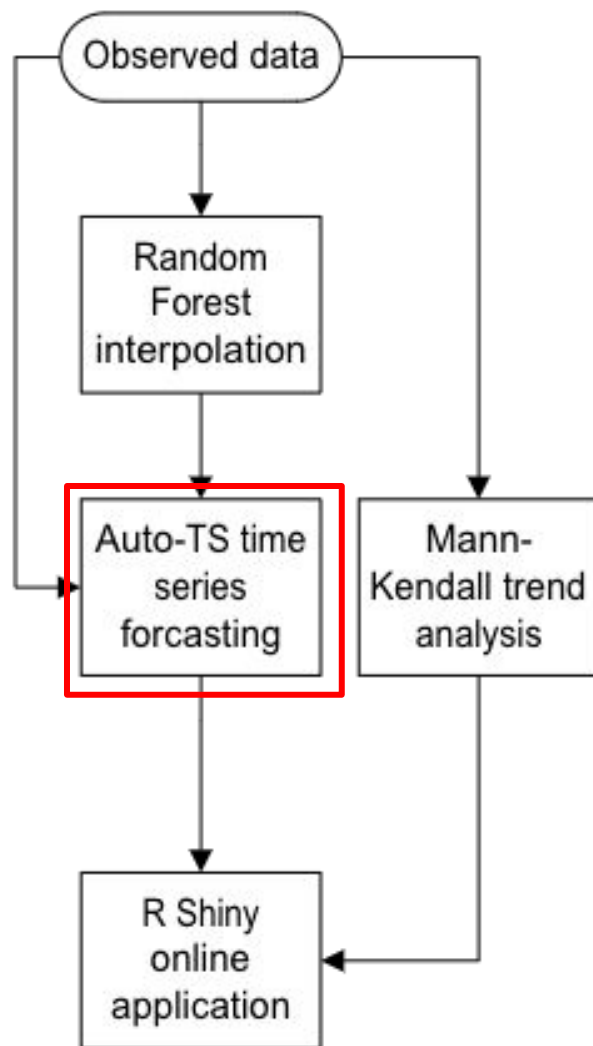
Random Forest Interpolation

TW-4 Historical Record

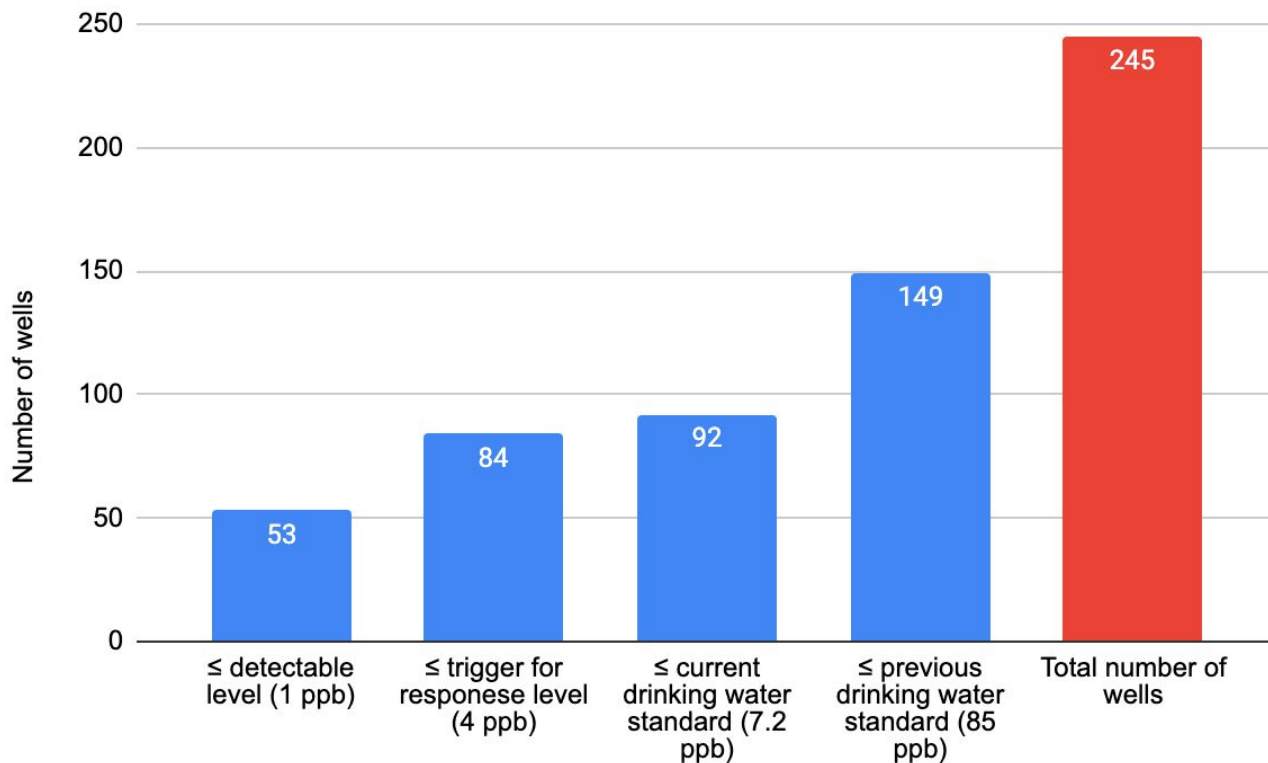


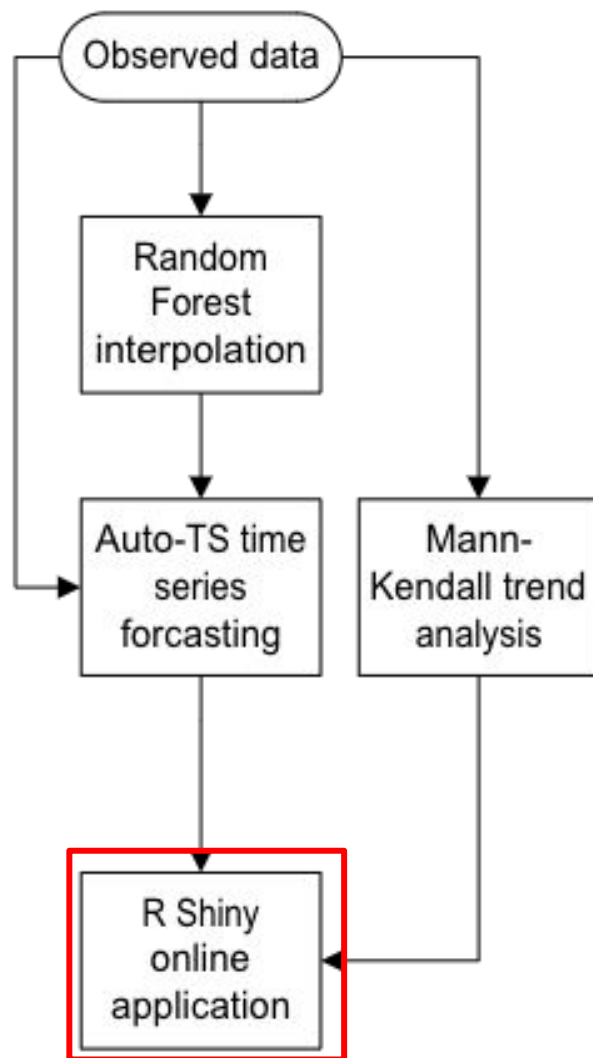
TW-4 Random Forest Interpolation





How many wells will meet criterion within five years?

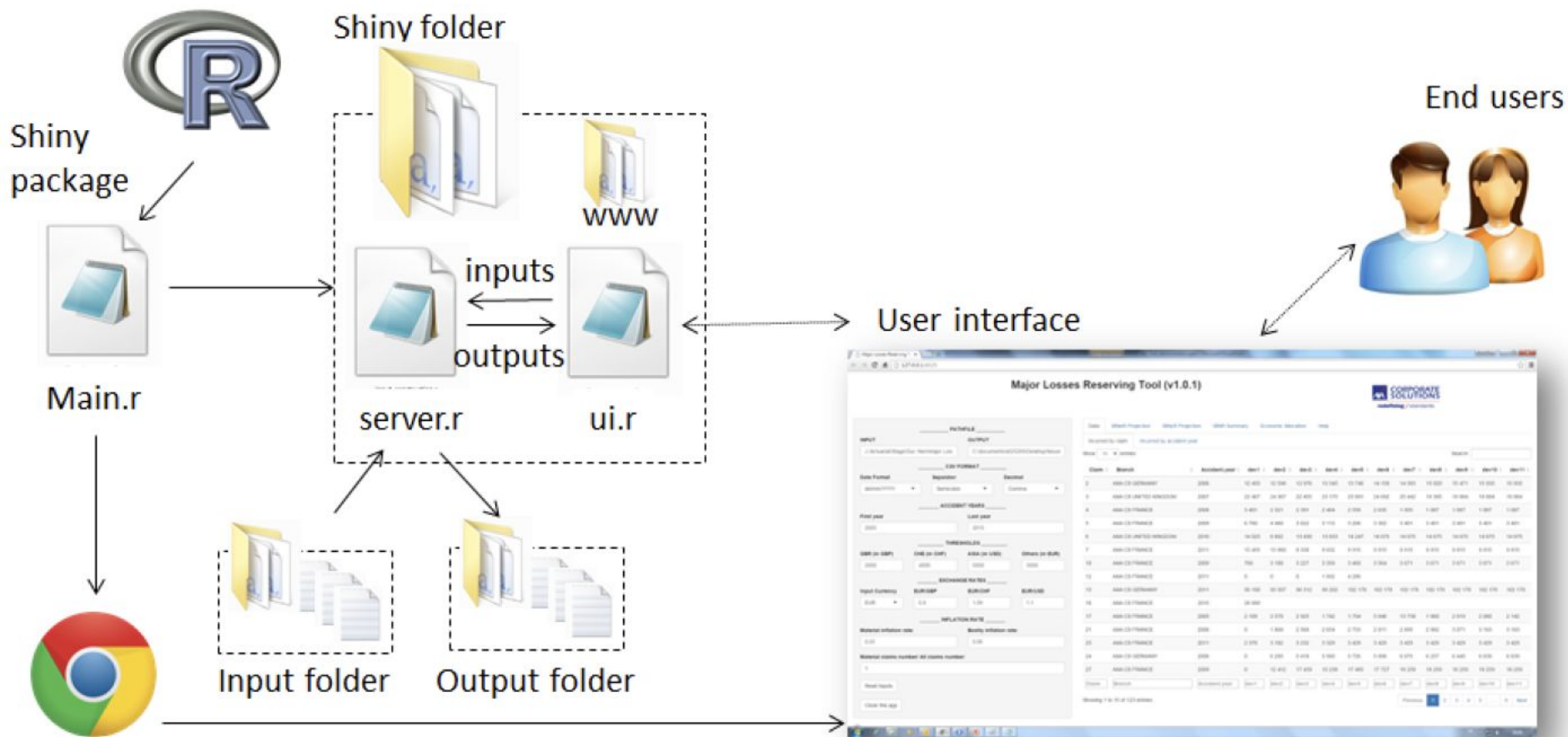




R Shiny Web Application



- Shiny = R + interactivity + web
- Framework for building **browser-based** applications
- Turns R code into **interactive and dynamic displays**
- Applications can be developed **entirely with R code**



Building a Shiny Application

ui.R : controls look
and layout of the app

```
library(shiny)

# Define UI for application that draws a histogram
shinyUI(fluidPage(

  # Application title
  titlePanel("Hello Shiny!"),

  # Sidebar with a slider input for the number of bins
  sidebarLayout(
    sidebarPanel(
      sliderInput("bins",
        "Number of bins:",
        min = 1,
        max = 50,
        value = 30)
    ),

    # Show a plot of the generated distribution
    mainPanel(
      plotOutput("distPlot")
    )
  )
))
```



server.R: instructions
used to build the app

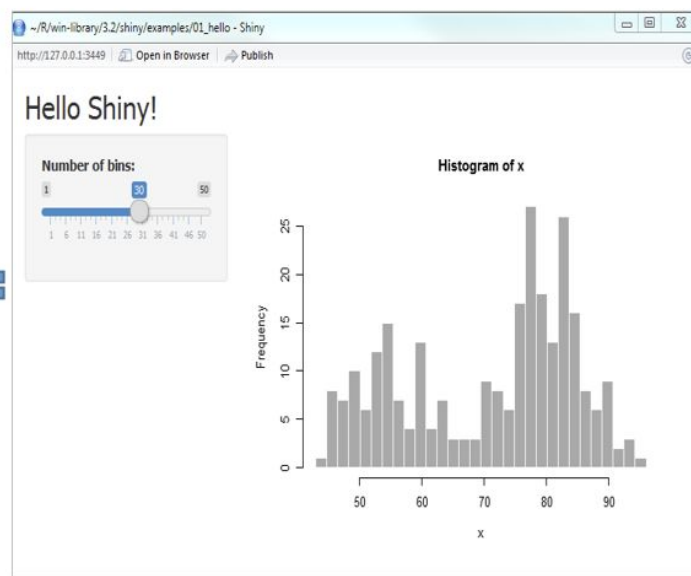
```
library(shiny)

# Define server logic required to draw a histogram
shinyServer(function(input, output) {

  # Expression that generates a histogram. The expression is
  # wrapped in a call to renderPlot to indicate that:
  #
  # 1) It is "reactive" and therefore should be automatically
  #    re-executed when inputs change
  # 2) Its output type is a plot

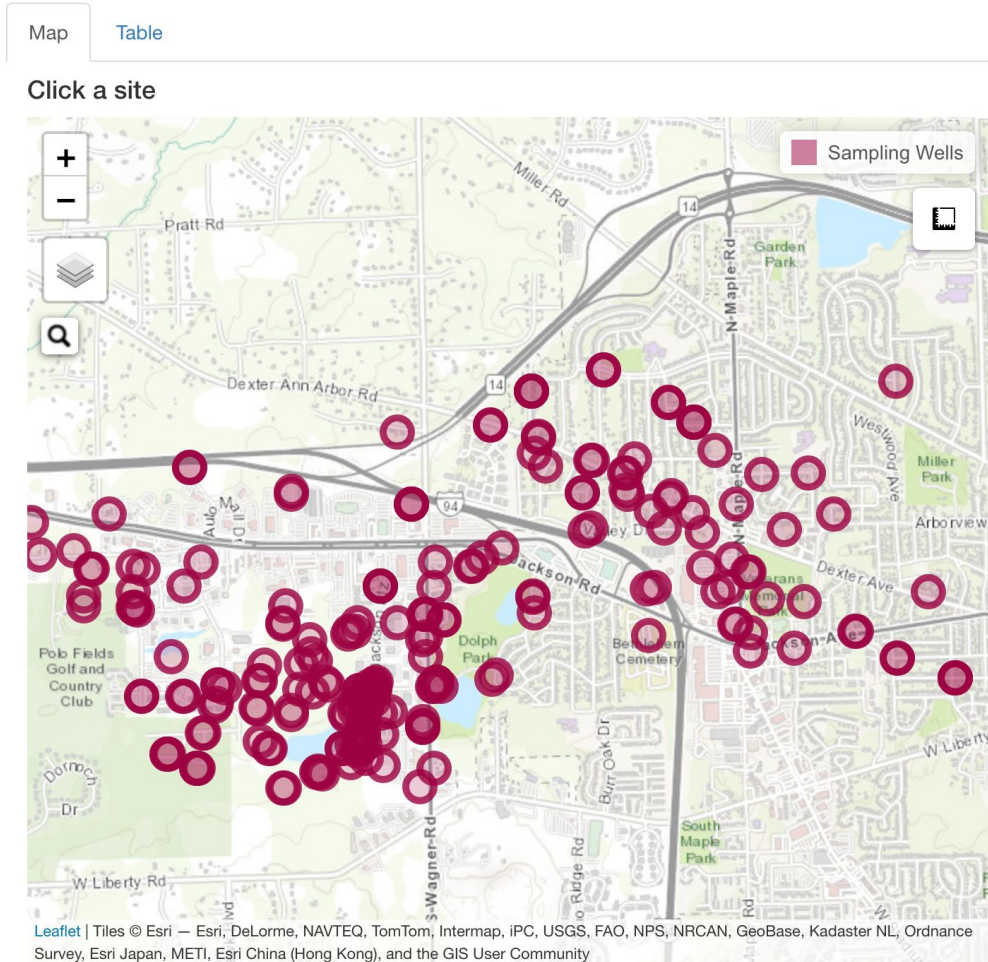
  output$distPlot <- renderPlot({
    x <- faithful[, 2] # Old Faithful Geyser data
    bins <- seq(min(x), max(x), length.out = input$bins + 1)

    # draw the histogram with the specified number of bins
    hist(x, breaks = bins, col = 'darkgray', border = 'white')
  })
})
```



Well Sites Map Input

- Show all individual monitoring well locations with concentration data available



Geographic Info Table Input

- Show all sampling wells and their associated geographic information (depth, elevation, latitude and longitude) and their well types

Map

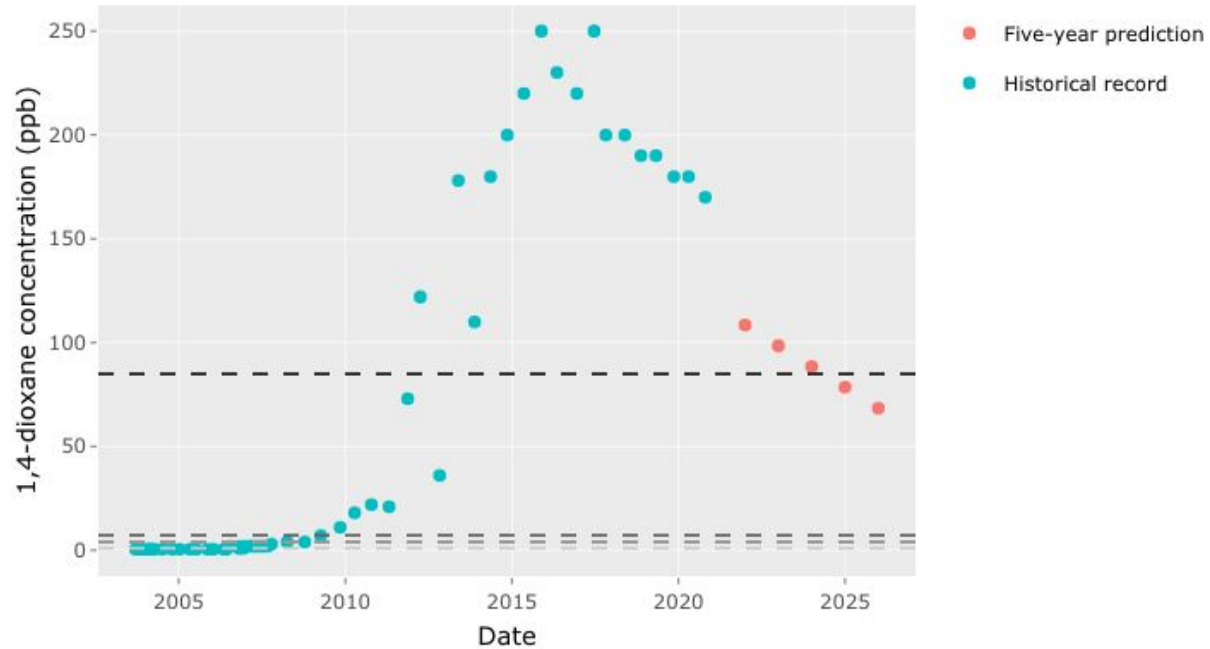
Table

Click a site

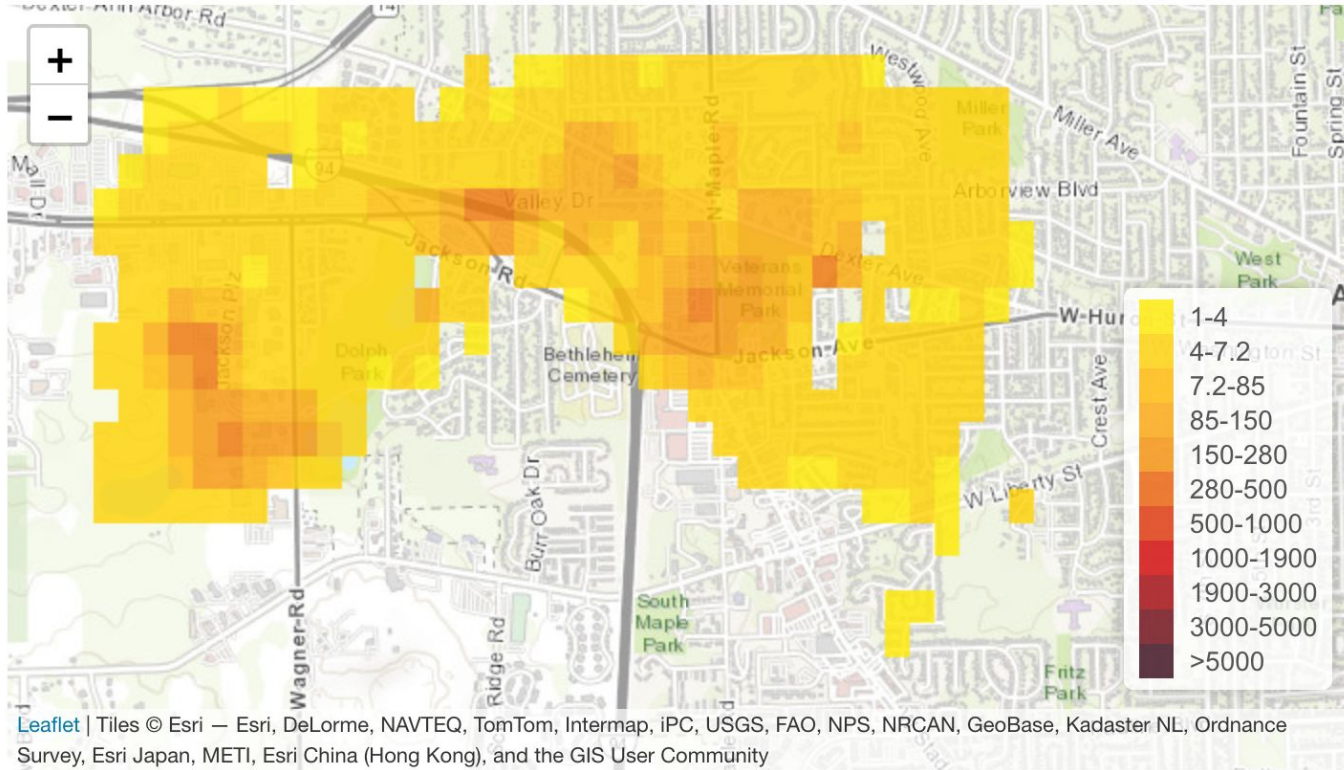
Search:

Well_Name	Depth	Elevation	Latitude	Longitude	Well_Types
110 Parkland Plaza	91	936.1181	42.2831878991157	-83.8142040421868	Residential Wells
170 Aprill	50	907.2557	42.2823095310774	-83.8079959541735	Residential Wells
175 Jackson Plaza	103	929.4347	42.2815607379006	-83.8012221620632	Monitoring Wells
2575 Valley	2	941.8386	42.2856315010442	-83.7826484201087	Residential Wells
2819 Dexter Rd	-9999	939.9844	42.2875484913914	-83.7872791612204	Monitoring Wells
3365 Jackson Rd	104	936.0822	42.2844648500619	-83.7961025975852	Monitoring Wells
3563 ELIZABETH RD	-9999	954.3443	42.2901487280406	-83.8012447612354	
373 Pinewood Deep	233	934.5783	42.2874114974318	-83.790018257077	Monitoring Wells
373 Pinewood Shallow	96	934.5783	42.2874114974318	-83.790018257077	Monitoring Wells
4141 Jackson Rd	98	936.7078	42.2843064836086	-83.8131476290099	Residential Wells
4401 Park West	-9999	933.5312	42.2841248755096	-83.8172779068422	Residential Wells
4470 Jackson Rd	-9999	918.6182	42.2864536739999	-83.8187727000281	Residential Wells
456 Clarendon	102	942.355	42.2865810912895	-83.7857566736153	Monitoring Wells
4601 Park 4 inch	52	898.2162	42.282339756526	-83.8202569871109	Residential Wells
4601 Park 6 inch	42	895.2655	42.282745538356	-83.8202858503823	Residential Wells
465 Dupont	181	928.4702	42.289177688323	-83.7929150910502	Monitoring Wells
4742 Park Rd	50	889.5266	42.2846366687432	-83.8229720957591	Residential Wells
5005 Jackson Rd	-9999	859.9006	42.2864875443625	-83.8258275996101	Residential Wells
5115 Jackson Rd	-9999	866.8431	42.2873257799033	-83.8271184245712	Residential Wells
697 South Wagner Rd	-9999	938.8018	42.2750421349773	-83.7990112958945	Residential Wells

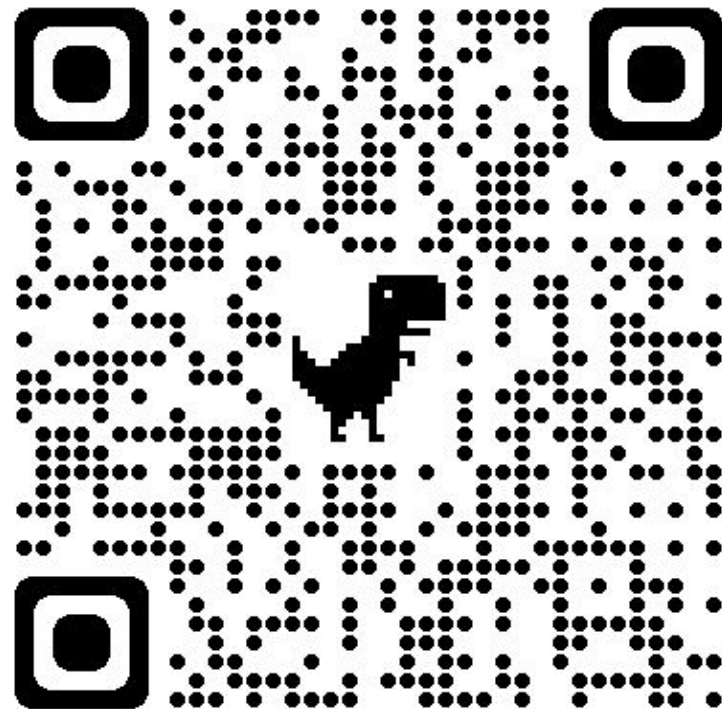
Well Data Forecasting Output



Plume Projection Output



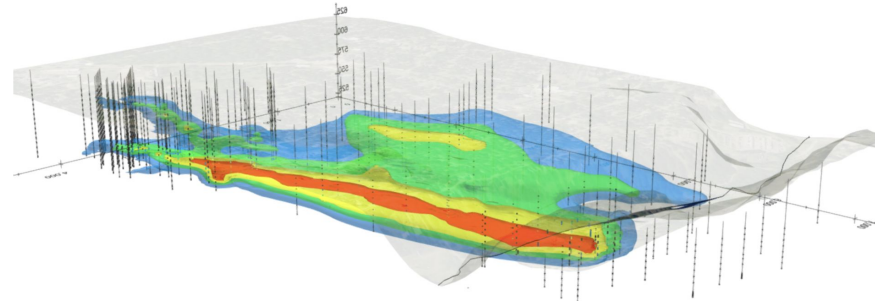
Shiny Demo



http://50.17.61.223:3838/gelman_shiny/

Limitations

- Unable to show **3-dimensional** plume distribution (i.e. depth to contamination or thickness of contaminated zone) in groundwater.
- **Not all** wells (samplings number ≤ 20) shown within the plume boundaries could be analyzed and forecasted.



Thank you!

Please don't hesitate to email if you have questions or feedbacks.

Yifan Luo

yifanluo@umich.edu

**DRINKING
TAP WATER**



**DRINKING FILTERED
WATER**



**DRINKING
FROM A LAKE**



**DRINKING
GROUNDWATER**

