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1 Rationale and Research Questions

#We perform analysis based on the following sub-questions. #How is groundwater table related to precipitation? #How is groundwater table level related to local river discharge? #How is ground water table level related to local withdraws?

2 Dataset Information

3 Exploratory Analysis

```
#Regular Water Resources
CapeFearRiverDischarge <- readNWISdv(siteNumbers = "02096500",
                                     parameterCd = "00060", # discharge (ft3/s)
                                     startDate = "1990-01-01",
                                     endDate = "2021-12-31")
names(CapeFearRiverDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(CapeFearRiverDischarge$Date), max(CapeFearRiverDischarge$Date))
```

```
## [1] "1990-01-01" "2021-12-31"
```

```
#"1990-01-01" "2021-12-31"
CapeFearRiverDischarge_Monthly <- CapeFearRiverDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Cape Fear River"))

FlatRiverDischarge <- readNWISdv(siteNumbers = "02085500",
                                 parameterCd = "00060", # discharge (ft3/s)
                                 startDate = "1990-01-01",
                                 endDate = "2021-12-31")
names(FlatRiverDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(FlatRiverDischarge$Date), max(FlatRiverDischarge$Date))
```

```
## [1] "1990-01-01" "2021-12-31"
```

```
#"1990-01-01" "2021-12-31"
FlatRiverDischarge_Monthly <- FlatRiverDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Flat River"))

LittleRiverDischarge <- readNWISdv(siteNumbers = "0208524975",
                                   parameterCd = "00060", # discharge (ft3/s)
                                   startDate = "1990-01-01",
                                   endDate = "2021-12-31")
names(LittleRiverDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(LittleRiverDischarge$Date), max(LittleRiverDischarge$Date))
```

```
## [1] "1995-10-24" "2021-12-31"
```

```
#"1995-10-24" "2021-12-31"
LittleRiverDischarge_Monthly <- LittleRiverDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
```

```
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Little River"))

#Emergency Water Resources
EnoRiverDischarge <- readNWISdv(siteNumbers = "02085070",
                                parameterCd = "00060", # discharge (ft3/s)
                                startDate = "1990-01-01",
                                endDate = "2021-12-31")
names(EnoRiverDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(EnoRiverDischarge$Date), max(EnoRiverDischarge$Date))
```

```
## [1] "1990-01-01" "2021-12-31"
```

```
#"1990-01-01" "2021-12-31"
EnoRiverDischarge_Monthly <- EnoRiverDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Eno River"))

#Surrounding Water Resources (Unused)
EllerbeCreekDischarge <- readNWISdv(siteNumbers = "0208675010",
                                parameterCd = "00060", # discharge (ft3/s)
                                startDate = "1990-01-01",
                                endDate = "2021-12-31")
names(EllerbeCreekDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(EllerbeCreekDischarge$Date), max(EllerbeCreekDischarge$Date))
```

```
## [1] "2008-08-01" "2021-12-31"
```

```
#"2008-08-01" "2021-12-31"
EllerbeCreekDischarge_Monthly <- EllerbeCreekDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Ellerbe Creek"))

SandyCreekDischarge <- readNWISdv(siteNumbers = "0209722970",
                                parameterCd = "00060", # discharge (ft3/s)
                                startDate = "1990-01-01",
                                endDate = "2021-12-31")
names(SandyCreekDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(SandyCreekDischarge$Date), max(SandyCreekDischarge$Date))
```

```
## [1] "2008-08-01" "2021-12-31"
```

```
#"2008-08-01" "2021-12-31"
SandyCreekDischarge_Monthly <- SandyCreekDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Sandy Creek"))

ThirdForkCreekDischarge <- readNWISdv(siteNumbers = "0209725960",
                                      parameterCd = "00060", # discharge (ft3/s)
                                      startDate = "1990-01-01",
                                      endDate = "2021-12-31")
names(ThirdForkCreekDischarge)[4:5] <- c("Discharge", "Approval.Code")
c(min(ThirdForkCreekDischarge$Date), max(ThirdForkCreekDischarge$Date))
```

```
## [1] "2017-06-16" "2021-12-31"
```

```
#"2017-06-16" "2021-12-31"
ThirdForkCreekDischarge_Monthly <- ThirdForkCreekDischarge %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Mean_Discharge_Bymonth = mean(Discharge),
            River = paste("Third Fork Creek"))
```

```
GroundParams <- whatNWISdata(siteNumbers = "355944079013401")
DurhamGroundwater <- readNWISdv(siteNumbers = "355944079013401",
                                parameterCd = "72019", # /62610/Groundwater level abov
                                statCd = "00002",
                                startDate = "2014-01-01",
                                endDate = "2021-12-31")
names(DurhamGroundwater)[4:5] <- c("Groundwater_Table_feet", "Approval.Code")
c(min(DurhamGroundwater$Date), max(DurhamGroundwater$Date))
```

```
## [1] "2014-01-01" "2021-12-31"
```

```
#
```

```
#the PSWID of Durham
durham_pswid = '03-32-010'
#years with records
the_years = c(2018:2021)

#Scrap Function
scrape.totalwithdrawal <- function(the_pswid, the_year){
  the_website <- read_html(paste0('https://www.ncwater.org/WUDC/app/LWSP/report.php?pwsi
                                  the_pswid, '&year=', the_year))
```

```
  water_system_name_tag <- 'div+ table tr:nth-child(1) td:nth-child(2)'
  ownership_tag <- 'div+ table tr:nth-child(2) td:nth-child(4)'
  avg_daily_use_tag <- '.fancy-table:nth-child(31) th+ td'

  water_system_name <- the_website %>% html_nodes(water_system_name_tag) %>% html_text()
  ownership <- the_website %>%   html_nodes(ownership_tag) %>%  html_text()
  avg_daily_use <- the_website %>% html_nodes(avg_daily_use_tag) %>% html_text()

  df_withdrawals <- data.frame("Year" = rep(the_year,12),
                               "Month" = rep(1:12),
                               "Avg_Daily_Use_mgd" = as.numeric(avg_daily_use)) %>%
    mutate(Water_System_name = !!water_system_name,
         Ownership = !!ownership,
         Date = my(paste(Month,"-",Year)))

  print(paste('The Pswid =', the_pswid, ', The Year =', the_year))
  return(df_withdrawals)
}

total_withdrawal <- map(the_years, scrape.totalwithdrawal, the_pswid = durham_pswid)
```

```
## [1] "The Pswid = 03-32-010 , The Year = 2018"
## [1] "The Pswid = 03-32-010 , The Year = 2019"
## [1] "The Pswid = 03-32-010 , The Year = 2020"
## [1] "The Pswid = 03-32-010 , The Year = 2021"
```

```
total_withdrawal <- bind_rows(total_withdrawal)
```

```
#the PSWID of Durham
durham_pswid = '03-32-010'
#years with records
the_years = c(2018:2021)

scrape.withdrawal.distribution <- function(the_pswid, the_year){
  the_website <- read_html(paste0('https://www.ncwater.org/WUDC/app/LWSP/report.php?pwsi
                                  the_pswid, '&year=', the_year))

  water_system_name_tag <- 'div+ table tr:nth-child(1) td:nth-child(2)'
  ownership_tag <- 'div+ table tr:nth-child(2) td:nth-child(4)'
  stream_name_tag <- '.fancy-table:nth-child(35) .left:nth-child(1)'
  avg_daily_use_tag <- '.fancy-table:nth-child(35) .left~ .left+ td'
  the_numberofdaysused_tag <- '.fancy-table:nth-child(35) td:nth-child(4)'

  water_system_name <- the_website %>% html_nodes(water_system_name_tag) %>% html_text()
  ownership <- the_website %>%   html_nodes(ownership_tag) %>%  html_text()
```

```
  stream_name <- the_website %>% html_nodes(stream_name_tag) %>% html_text()
  avg_daily_use <- the_website %>% html_nodes(avg_daily_use_tag) %>% html_text()
  the_numberofdaysused <- the_website %>% html_nodes(the_numberofdaysused_tag) %>% html_

  df_withdrawals <- data.frame("Year" = rep(the_year,5),
                               "Stream_Name" = stream_name,
                               "Avg_Daily_Use_mgd" = as.numeric(avg_daily_use),
                               "Number_of_Days_Used" = as.numeric(the_numberofdaysused))
    mutate(Water_System_name = !!water_system_name,
         Ownership = !!ownership)

  print(paste('The Pswid =', the_pswid, ', The Year =', the_year))
  return(df_withdrawals)
}

withdrawal_distribution <- map(the_years, scrape.withdrawal.distribution, the_pswid = du
```

```
## [1] "The Pswid = 03-32-010 , The Year = 2018"
## [1] "The Pswid = 03-32-010 , The Year = 2019"
## [1] "The Pswid = 03-32-010 , The Year = 2020"
## [1] "The Pswid = 03-32-010 , The Year = 2021"
```

```
withdrawal_distribution <- bind_rows(withdrawal_distribution)
```

```
#Water-use industries' sites
#https://www.ncwater.org/WUDC/app/WWATR/report
Brentwood <- "0218-0068"
CanterburyEstates <- "0218-0086"
CardensCreek <- "0218-0088"
FoxRun <- "0218-0199"
Greymoss <- "0218-0229"
Hardscrabble <- "0218-0238"
LakeRidge <- "0218-0313"
Masonwoods <- "0218-0349"
RedMountain <- "0218-0460"
TrappersCreek <- "0218-0608"
Tyndrum <- "0218-0619"
Wexford <- "0218-0646"
WillowHill <- "0218-0658"
HeatherGlen <- "0378-0038"
ColvardFarms <- "0427-0001"
CroasdaileCountryClub <- "0419-0001"
RougemontQuarry <- "0340-0003"
Durham.sites <- c(Brentwood, CanterburyEstates, CardensCreek, FoxRun, Greymoss, Hardscra
```

```r
#years with records
the_years = c(2007:2021)

#Scraping Function
scrape.industrywithdrawals <- function(the_year, the_facility){
  #Retrieve the website contents
  the_website <- read_html(paste0('https://www.ncwater.org/WUDC/app/WWATR/report/view/',
                                  the_facility, '/', the_year))

  #Set the element address variables (determined in the previous step)
  the_registrant_tag <- '.table tr:nth-child(1) td:nth-child(2)'
  the_facility_name_tag <- 'tr:nth-child(2) th+ .left:nth-child(2)'
  the_facility_id_tag <- 'tr:nth-child(2) .left~ .left+ td.left'
  the_data_tag <- '.table:nth-child(7) td:nth-child(7) , .table:nth-child(7) td:nth-chil
  the_numberofdaysused_tag <- '.table:nth-child(7) th+ td'

  #Scrape the data items
  the_registrant <- the_website %>% html_nodes(the_registrant_tag) %>% html_text()
  the_facility_name <- the_website %>%   html_nodes(the_facility_name_tag) %>%  html_tex
  the_facility_type <- the_website %>% html_nodes(the_facility_id_tag) %>% html_text()
  avg_withdrawals <- the_website %>% html_nodes(the_data_tag) %>% html_text()
  the_numberofdaysused <- the_website %>% html_nodes(the_numberofdaysused_tag) %>% html_

  #Convert to a dataframe
  df_withdrawals <- data.frame("Year" = rep(the_year,12),
                               "Month" = rep(1:12),
                               "Avg_Withdrawals_mgd" = as.numeric(avg_withdrawals),
                               "Number_of_Days_Used" = as.numeric(the_numberofdaysused))
    mutate(Registrant = !!the_registrant,
           Facility_name = !!the_facility_name,
           Facility_type = !!the_facility_type,
           Date = my(paste(Month,"-",Year)))

  #Pause for a moment - scraping etiquette
  #Sys.sleep(1) #uncomment this if you are doing bulk scraping!

  #Return the dataframe
  return(df_withdrawals)
}

industry_withdrawal <- cross2(the_years, Durham.sites) %>%
  map(lift(scrape.industrywithdrawals)) %>%
  bind_rows()
```

```r
industry_withdrawal_Monthly <- industry_withdrawal %>%
  select(Date, Avg_Withdrawals_mgd) %>%
  mutate(Month = format(Date,"%Y-%m")) %>%
  group_by(Month) %>%
  summarise(Avg_Industrial_Withdrawals_mgd = sum(Avg_Withdrawals_mgd))
```

```r
#Precipitation
PreciParams <- whatNWISdata(siteNumbers = "355852078572045")
DurhamPrecipitaion <- readNWISdv(siteNumbers = "355852078572045",
                                 parameterCd = "00045", # precipitation (inches)
                                 statCd = "00006",
                                 startDate = "2009-01-01",
                                 endDate = "2021-12-31")
names(DurhamPrecipitaion)[4:5] <- c("Precipitaion_inches", "Approval.Code")
c(min(DurhamPrecipitaion$Date), max(DurhamPrecipitaion$Date))
```

```
## [1] "2009-01-01" "2021-12-31"
```

```r
#
```

```r
#the PSWID of Durham
durham_pswid = '03-32-010'
#years with records
the_years = c(2018:2021)

scrape.totalwastewater <- function(the_pswid, the_year){
  the_website <- read_html(paste0('https://www.ncwater.org/WUDC/app/LWSP/report.php?pwsi
                                  the_pswid, '&year=', the_year))

  water_system_name_tag <- 'div+ table tr:nth-child(1) td:nth-child(2)'
  ownership_tag <- 'div+ table tr:nth-child(2) td:nth-child(4)'
  avg_daily_discharge_tag <- '.fancy-table:nth-child(50) td'

  water_system_name <- the_website %>% html_nodes(water_system_name_tag) %>% html_text()
  ownership <- the_website %>%   html_nodes(ownership_tag) %>%  html_text()
  avg_daily_discharge <- the_website %>% html_nodes(avg_daily_discharge_tag) %>% html_te

  df_wastewaters <- data.frame("Year" = rep(the_year,12),
                               "Month" = rep(1:12),
                               "Avg_Daily_Use_mgd" = as.numeric(avg_daily_discharge)) %>
    mutate(Water_System_name = !!water_system_name,
         Ownership = !!ownership,
         Date = my(paste(Month,"-",Year)))

  print(paste('The Pswid =', the_pswid, ', The Year =', the_year))
  return(df_wastewaters)
```

```
}

total_wastewater <- map(the_years, scrape.totalwastewater, the_pswid = durham_pswid)
```

```
## [1] "The Pswid = 03-32-010 , The Year = 2018"
## [1] "The Pswid = 03-32-010 , The Year = 2019"
## [1] "The Pswid = 03-32-010 , The Year = 2020"
## [1] "The Pswid = 03-32-010 , The Year = 2021"
```

```
total_wastewater <- bind_rows(total_wastewater)
```

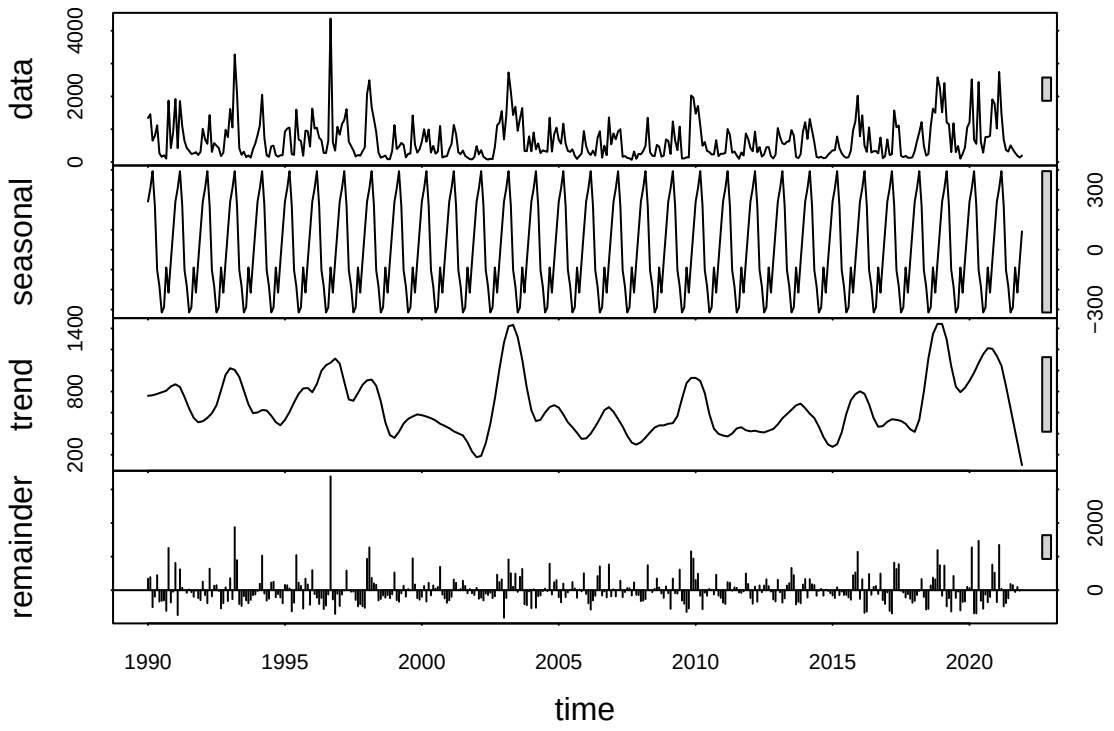
```
#the PSWID of Durham
durham_pswid = '03-32-010'
#years with records
the_years = c(2018:2021)

scrape.wastewater.distribution <- function(the_pswid, the_year){
  the_website <- read_html(paste0('https://www.ncwater.org/WUDC/app/LWSP/report.php?pwsi
                                  the_pswid, '&year=', the_year))

  water_system_name_tag <- 'div+ table tr:nth-child(1) td:nth-child(2)'
  ownership_tag <- 'div+ table tr:nth-child(2) td:nth-child(4)'
  stram_name_tag <- '.fancy-table:nth-child(55) .left:nth-child(6)'
  basin_name_tag <- '.left:nth-child(7)'
  avg_daily_discharge_tag <- '.fancy-table:nth-child(55) td:nth-child(4)'

  water_system_name <- the_website %>% html_nodes(water_system_name_tag) %>% html_text()
  ownership <- the_website %>%   html_nodes(ownership_tag) %>%  html_text()
  stream_name <- the_website %>% html_nodes(stram_name_tag) %>% html_text()
  basin_name <- the_website %>% html_nodes(basin_name_tag) %>% html_text()
  avg_daily_discharge <- the_website %>% html_nodes(avg_daily_discharge_tag) %>% html_te

  df_wastewater <- data.frame("Year" = rep(the_year,2),
                              "Recieving_Stream" = stream_name,
                             "Recieving_Basin" = basin_name,
                              "Avg_Daily_Discharge_mgd" = as.numeric(avg_daily_discharg
    mutate(Water_System_name = !!water_system_name,
         Ownership = !!ownership)

  print(paste('The Pswid =', the_pswid, ', The Year =', the_year))
  return(df_wastewater)
}

wastewater_distribution <- map(the_years, scrape.wastewater.distribution, the_pswid = du
```

```
## [1] "The Pswid = 03-32-010 , The Year = 2018"
## [1] "The Pswid = 03-32-010 , The Year = 2019"
## [1] "The Pswid = 03-32-010 , The Year = 2020"
## [1] "The Pswid = 03-32-010 , The Year = 2021"
```

```
wastewater_distribution <- bind_rows(wastewater_distribution)
```

4 Analysis

```
CapeFearRiver_timeseries <- ts(CapeFearRiverDischarge_Monthly$Mean_Discharge_Bymonth, fr
                               start = c(1990, 1, 1), end = c(2021, 12, 1))
CapeFearRiver_Decomposed <- stl(CapeFearRiver_timeseries, s.window = "periodic")
plot(CapeFearRiver_Decomposed)
```



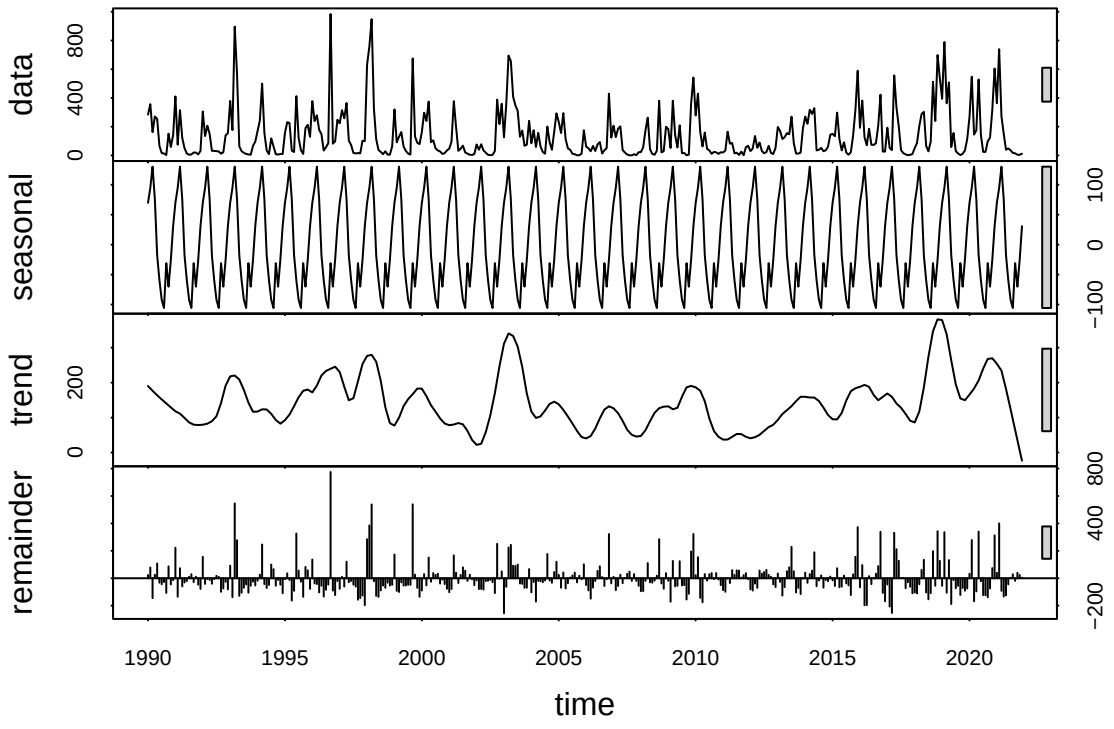

```
CapeFearRiver_trend <- smk.test(CapeFearRiver_timeseries)
CapeFearRiver_trend
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  CapeFearRiver_timeseries
## z = -0.98775, p-value = 0.3233
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##     S  varS
##  -212 45632
```

```
summary(CapeFearRiver_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: CapeFearRiver_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
##
## H0
##                       S   varS    tau      z Pr(>|z|)
## Season 1:   S = 0  -98 3802.7 -0.198 -1.573  0.11572
## Season 2:   S = 0  -18 3802.7 -0.036 -0.276  0.78279
## Season 3:   S = 0  -72 3802.7 -0.145 -1.151  0.24958
## Season 4:   S = 0  -78 3802.7 -0.157 -1.249  0.21179
## Season 5:   S = 0   32 3802.7  0.065  0.503  0.61517
## Season 6:   S = 0   24 3802.7  0.048  0.373  0.70916
## Season 7:   S = 0  -48 3802.7 -0.097 -0.762  0.44596
## Season 8:   S = 0   24 3802.7  0.048  0.373  0.70916
## Season 9:   S = 0   12 3802.7  0.024  0.178  0.85842
## Season 10:  S = 0   -4 3802.7 -0.008 -0.049  0.96120
## Season 11:  S = 0   -4 3802.7 -0.008 -0.049  0.96120
## Season 12:  S = 0   18 3802.7  0.036  0.276  0.78279
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#p-value is 0.3233, so there is no trend present in Cape Fear River.

FlatRiver_timeseries <- ts(FlatRiverDischarge_Monthly$Mean_Discharge_Bymonth, frequency
                           start = c(1990, 1, 1), end = c(2021, 12, 1))
FlatRiver_Decomposed <- stl(FlatRiver_timeseries, s.window = "periodic")
plot(FlatRiver_Decomposed)
```




```
FlatRiver_trend <- smk.test(FlatRiver_timeseries)
FlatRiver_trend
```

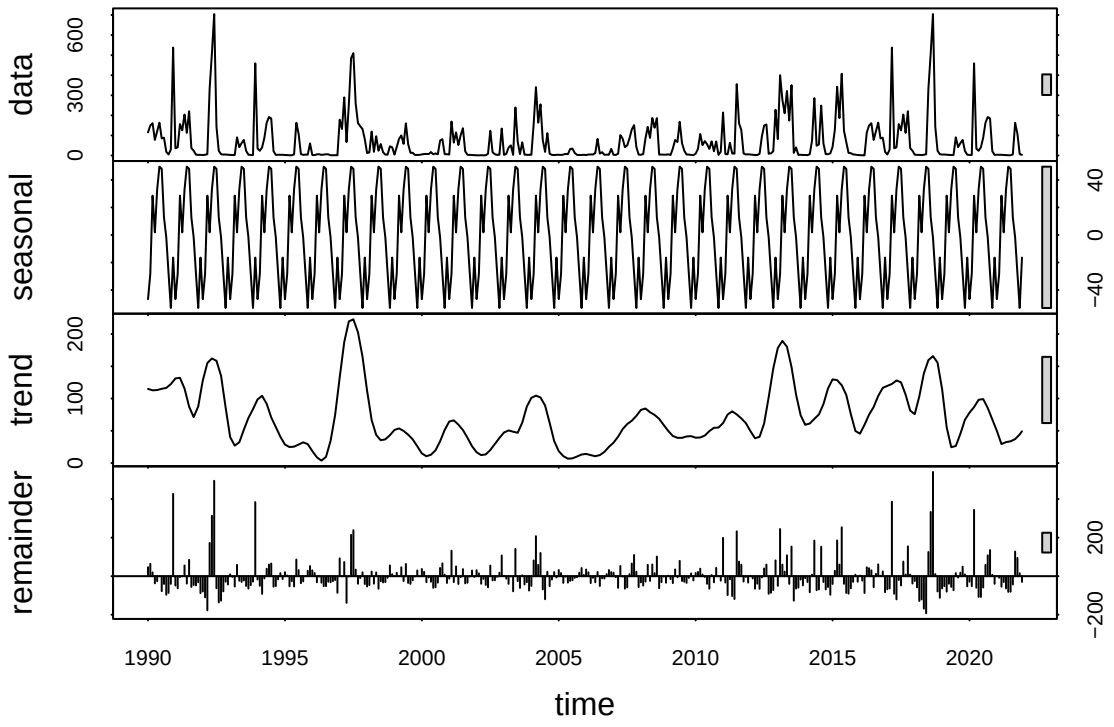
```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  FlatRiver_timeseries
## z = 0.84731, p-value = 0.3968
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##     S  varS
##   182 45632
```

```
summary(FlatRiver_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: FlatRiver_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
```

```
##
## H0
##                        S   varS    tau      z Pr(>|z|)
## Season 1:   S = 0  -76 3802.7 -0.153 -1.216 0.223896
## Season 2:   S = 0    4 3802.7  0.008  0.049 0.961199
## Season 3:   S = 0  -92 3802.7 -0.185 -1.476 0.140025
## Season 4:   S = 0  -18 3802.7 -0.036 -0.276 0.782794
## Season 5:   S = 0  108 3802.7  0.218  1.735 0.082712 .
## Season 6:   S = 0  110 3802.7  0.222  1.768 0.077129 .
## Season 7:   S = 0   38 3802.7  0.077  0.600 0.548500
## Season 8:   S = 0   36 3802.7  0.073  0.568 0.570323
## Season 9:   S = 0   58 3802.7  0.117  0.924 0.355310
## Season 10:  S = 0  -18 3802.7 -0.036 -0.276 0.782794
## Season 11:  S = 0    2 3802.7  0.004  0.016 0.987062
## Season 12:  S = 0   30 3802.7  0.060  0.470 0.638157
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#p-value is 0.3968, so there is no trend present in Flat River.

LittleRiver_timeseries <- ts(LittleRiverDischarge_Monthly$Mean_Discharge_Bymonth, freque
                             start = c(1990, 1, 1), end = c(2021, 12, 1))
LittleRiver_Decomposed <- stl(LittleRiver_timeseries, s.window = "periodic")
plot(LittleRiver_Decomposed)
```




```
LittleRiver_trend <- smk.test(LittleRiver_timeseries)
LittleRiver_trend
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  LittleRiver_timeseries
## z = 0.82859, p-value = 0.4073
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##     S  varS
##   178 45632
```

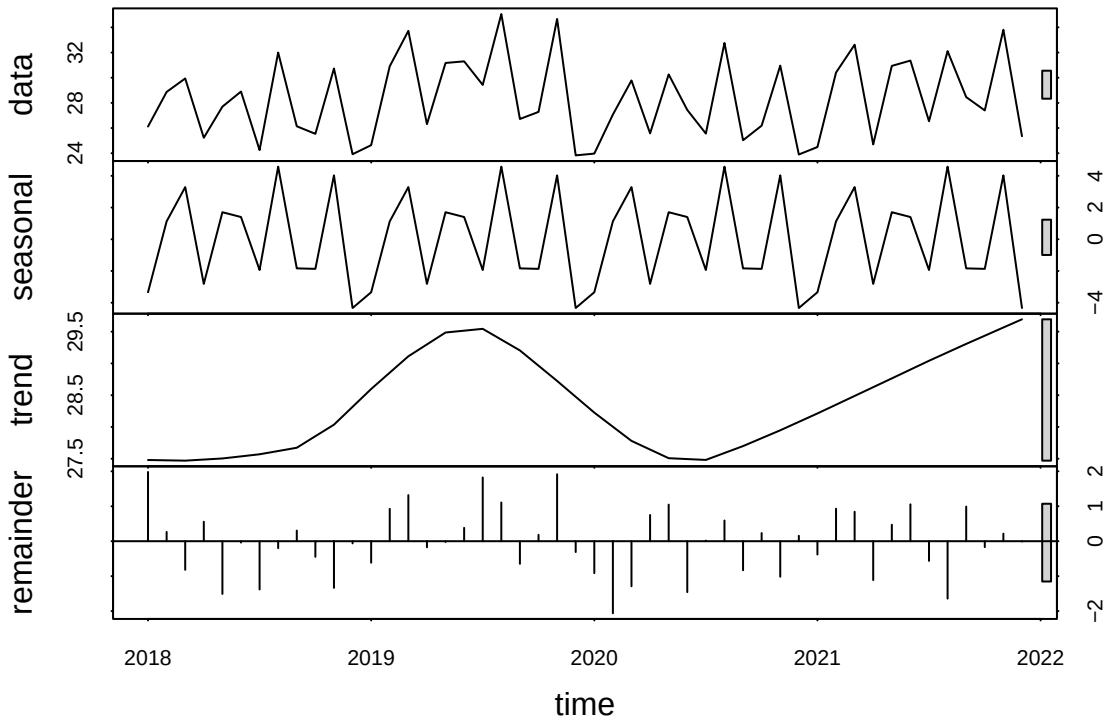
```
summary(LittleRiver_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: LittleRiver_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
```

```
##
## H0
##                        S   varS    tau      z  Pr(>|z|)
## Season 1:   S = 0   -24 3802.7 -0.048 -0.373 0.7091645
## Season 2:   S = 0   -60 3802.7 -0.121 -0.957 0.3386830
## Season 3:   S = 0   -16 3802.7 -0.032 -0.243 0.8078142
## Season 4:   S = 0   -72 3802.7 -0.145 -1.151 0.2495808
## Season 5:   S = 0   -76 3802.7 -0.153 -1.216 0.2238958
## Season 6:   S = 0  -120 3802.7 -0.242 -1.930 0.0536368  .
## Season 7:   S = 0   -18 3802.7 -0.036 -0.276 0.7827941
## Season 8:   S = 0    94 3802.7  0.190  1.508 0.1315212
## Season 9:   S = 0   202 3802.7  0.407  3.260 0.0011161 **
## Season 10:   S = 0  194 3802.7  0.391  3.130 0.0017494 **
## Season 11:   S = 0  126 3802.7  0.254  2.027 0.0426566  *
## Season 12:   S = 0  -52 3802.7 -0.105 -0.827 0.4082149
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#p-value is 0.4073, so there is no trend present in Little River.
```

```
#Total Withdrawals
total_withdrawal_timeseries <- ts(total_withdrawal$Avg_Daily_Use_mgd, frequency = 12,
                            start = c(2018, 1, 1), end = c(2021, 12, 1))
total_withdrawal_Decomposed <- stl(total_withdrawal_timeseries, s.window = "periodic")
plot(total_withdrawal_Decomposed)
```




```
total_withdrawal_trend <- smk.test(total_withdrawal_timeseries)
total_withdrawal_trend
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  total_withdrawal_timeseries
## z = 0.88252, p-value = 0.3775
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##    S varS
##   10  104
```

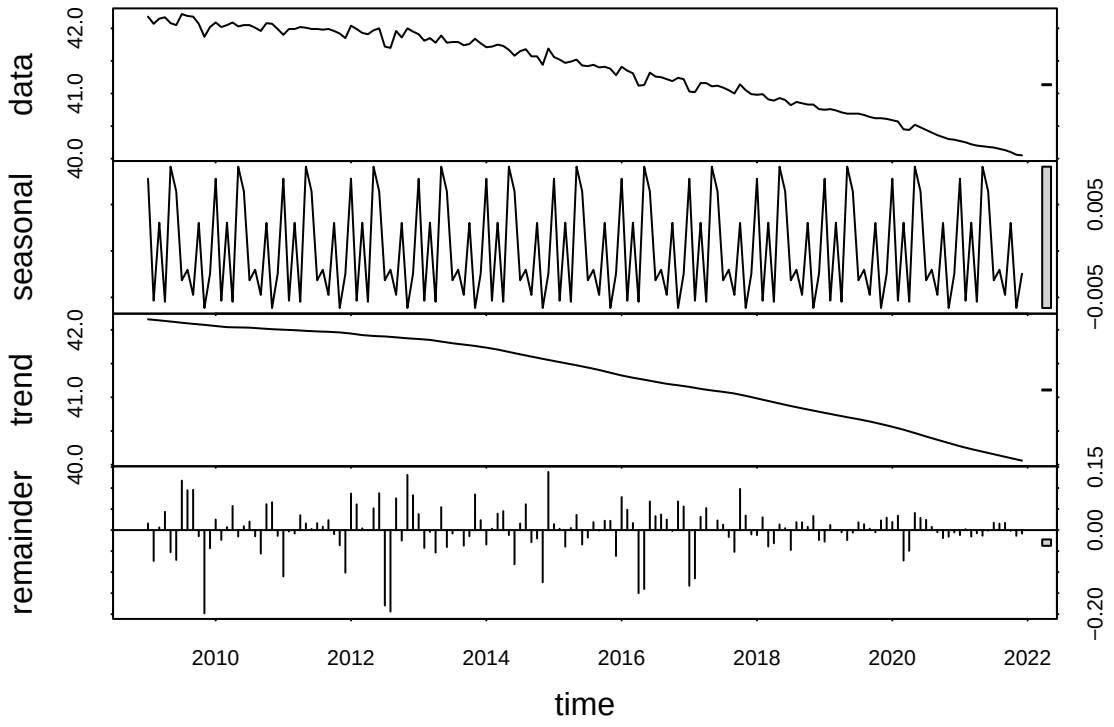
```
summary(total_withdrawal_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: total_withdrawal_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
```

```
##
## H0
##                       S varS    tau      z Pr(>|z|)
## Season 1:   S = 0  -4  8.7 -0.667 -1.019  0.30818
## Season 2:   S = 0   0  8.7  0.000  0.000  1.00000
## Season 3:   S = 0   0  8.7  0.000  0.000  1.00000
## Season 4:   S = 0  -2  8.7 -0.333 -0.340  0.73410
## Season 5:   S = 0   2  8.7  0.333  0.340  0.73410
## Season 6:   S = 0   2  8.7  0.333  0.340  0.73410
## Season 7:   S = 0   2  8.7  0.333  0.340  0.73410
## Season 8:   S = 0   0  8.7  0.000  0.000  1.00000
## Season 9:   S = 0   2  8.7  0.333  0.340  0.73410
## Season 10:   S = 0  4  8.7  0.667  1.019  0.30818
## Season 11:   S = 0  2  8.7  0.333  0.340  0.73410
## Season 12:   S = 0  2  8.7  0.333  0.340  0.73410
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#p-value is 0.3775, so there is no trend present in Total Withdrawals.
```

```
DurhamGroundwater_timeseries <- ts(DurhamGroundwater$Groundwater_Table_feet, frequency =
                          start = c(2009, 1, 1), end = c(2021, 12, 1))
DurhamGroundwater_Decomposed <- stl(DurhamGroundwater_timeseries, s.window = "periodic")
plot(DurhamGroundwater_Decomposed)
```




```
DurhamGroundwater_trend <- smk.test(DurhamGroundwater_timeseries)
DurhamGroundwater_trend
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  DurhamGroundwater_timeseries
## z = -15.964, p-value < 2.2e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##    S varS
## -907 3221
```

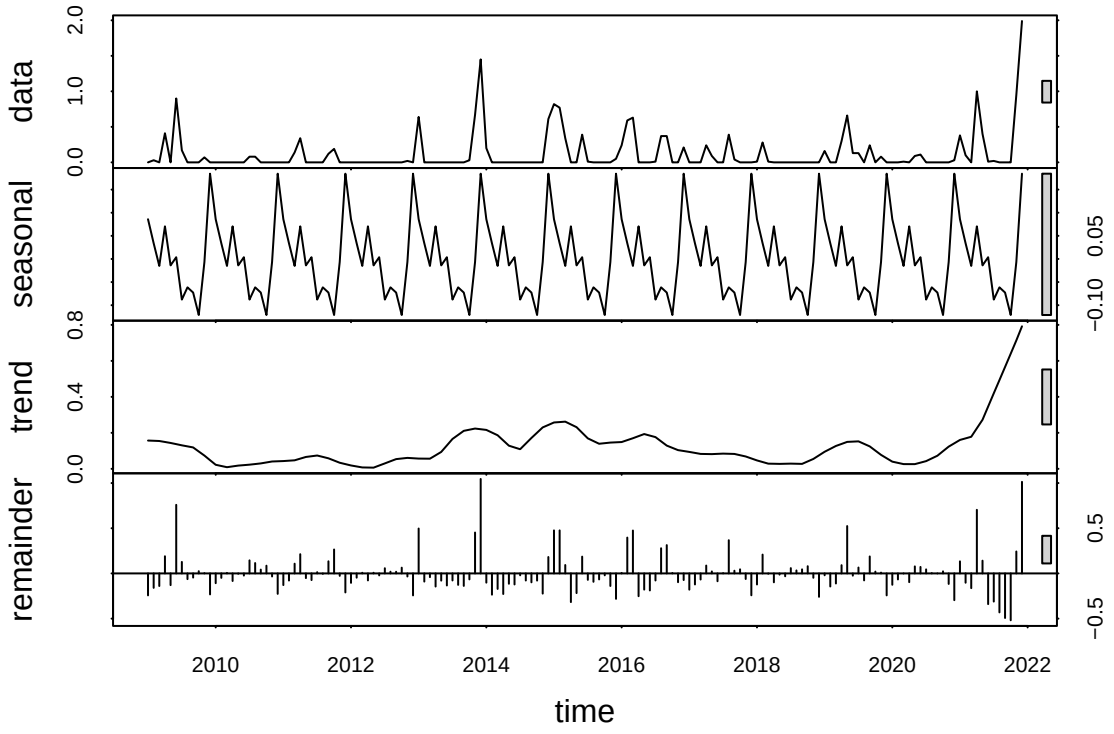
```
summary(DurhamGroundwater_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: DurhamGroundwater_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
```

```
##
## H0
##                        S  varS    tau      z   Pr(>|z|)
## Season 1:   S = 0  -74 268.7 -0.949 -4.454 8.4423e-06 ***
## Season 2:   S = 0  -77 267.7 -0.994 -4.645 3.3954e-06 ***
## Season 3:   S = 0  -78 268.7 -1.000 -4.698 2.6313e-06 ***
## Season 4:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 5:   S = 0  -78 268.7 -1.000 -4.698 2.6313e-06 ***
## Season 6:   S = 0  -75 267.7 -0.968 -4.523 6.0945e-06 ***
## Season 7:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 8:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 9:   S = 0  -75 267.7 -0.968 -4.523 6.0945e-06 ***
## Season 10:   S = 0 -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 11:   S = 0 -70 268.7 -0.897 -4.210 2.5581e-05 ***
## Season 12:   S = 0 -76 268.7 -0.974 -4.576 4.7471e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#p-value is less than 0.05, so there is no trend present in Total Withdrawals.
```

```
DurhamPrecipitaion_timeseries <- ts(DurhamPrecipitaion$Precipitaion_inches, frequency =
                          start = c(2009, 1, 1), end = c(2021, 12, 1))
DurhamPrecipitaion_Decomposed <- stl(DurhamPrecipitaion_timeseries, s.window = "periodic
plot(DurhamPrecipitaion_Decomposed)
```




```
DurhamPrecipitaion_trend <- smk.test(DurhamGroundwater_timeseries)
DurhamPrecipitaion_trend
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data:  DurhamGroundwater_timeseries
## z = -15.964, p-value < 2.2e-16
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##    S varS
## -907 3221
```

```
summary(DurhamPrecipitaion_trend)
```

```
##
##  Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: DurhamGroundwater_timeseries
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
```

```
##
## H0
##                       S  varS    tau      z   Pr(>|z|)
## Season 1:   S = 0  -74 268.7 -0.949 -4.454 8.4423e-06 ***
## Season 2:   S = 0  -77 267.7 -0.994 -4.645 3.3954e-06 ***
## Season 3:   S = 0  -78 268.7 -1.000 -4.698 2.6313e-06 ***
## Season 4:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 5:   S = 0  -78 268.7 -1.000 -4.698 2.6313e-06 ***
## Season 6:   S = 0  -75 267.7 -0.968 -4.523 6.0945e-06 ***
## Season 7:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 8:   S = 0  -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 9:   S = 0  -75 267.7 -0.968 -4.523 6.0945e-06 ***
## Season 10:   S = 0 -76 268.7 -0.974 -4.576 4.7471e-06 ***
## Season 11:   S = 0 -70 268.7 -0.897 -4.210 2.5581e-05 ***
## Season 12:   S = 0 -76 268.7 -0.974 -4.576 4.7471e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

4.1 Question 1: <insert specific question here and add additional subsections for additional questions below, if needed> Is there a relationship between surface water flow and groundwater levels in Durham region?

4.2 Question 2: How much is surface water affected by municipal withdrawal and precipitation recharge?

5 Summary and Conclusions

6 References

<add references here if relevant, otherwise delete this section>