Reservoir Long Term Rainfall

May 23, 2018

1 Summary

The long term rainfall data (between 1994 and 2018) at the 4 major reservoirs were plotted and examined for any trends. Plots of the monthly, annual, maximum, and minimum values showed no significant deviations from "normal" rainfall patterns. It is recommended that this study be conducted with a longer dataset if possible.

2 Aim

There's been a lot of speculation that rainfall has been decreasing over the years, causing water woes throughout Trinidad and Tobago. Here I will examine the historical monthly rainfall values at the 4 major reservoirs (Caroni-Arena, Hollis, Navet, and Hillsborough in Tobago) to look for any evidence that this is true. I have months from 1994 to 2018. That's not enough but let's go anyway.

```
In [1]: import pandas as pd
        %matplotlib inline
```

3 Data Prep

```
In [2]: df = pd.read_csv("ReservoirRainfall.csv")
        df.head()
```

Out[2]:

	Date	Caroni	Navet	Hollis	Hillsborough
0	03/01/2018	123.8	41.8	151.2	32.8
1	02/01/2018	100.6	82.8	128.0	150.0
2	01/01/2018	155.4	168.4	243.2	237.8
3	12/01/2017	401.2	467.4	536.0	316.8
4	11/01/2017	148.0	207.4	233.0	323.8

```
In [3]: df.Date = pd.to_datetime(df.Date)          #Changing the date column to date objects as
        df = df.sort_values('Date')
        df.set_index('Date', inplace=True)
        df.head()
```

```
Out[3]:              Caroni    Navet      Hollis  Hillsborough
        Date
        1994-01-01  101.542  123.155  163.765000       105.881
        1994-02-01   75.263   76.695   85.701000        61.204
        1994-03-01   40.502   62.063   84.786333        56.863
        1994-04-01   79.423   85.095  126.181000        73.508
        1994-05-01  143.962  165.100  195.160000       153.434

In [4]: df.describe()        #won't bother checking for nulls because I know there aren't any.

Out[4]:            Caroni       Navet      Hollis  Hillsborough
        count  291.000000  291.000000  291.000000    291.000000
        mean   181.688186  182.563564  247.968892    187.496416
        std    115.155944  120.852946  146.938104    119.619290
        min      4.200000    1.110000    1.363333      2.030000
        25%     87.500000   78.450000  126.440500     83.365000
        50%    171.600000  175.500000  245.850000    184.490000
        75%    263.950000  264.324500  347.110000    268.020000
        max    573.300000  604.500000  832.100000    557.800000
```

From the description of the reservoirs, everything looks as expected. Hollis clearly gets more rainfall than everybody else. I'm not sure if its surprising that Hillsborough gets more than Caroni and Navet. That max value at Hollis looks pretty crazy.

4 Rolling Averages

Plotting the rolling averages may give a better idea at how the rainfall patterns are changing. After some experimenting, I've found that a rolling window of 24 months gives the best representation.

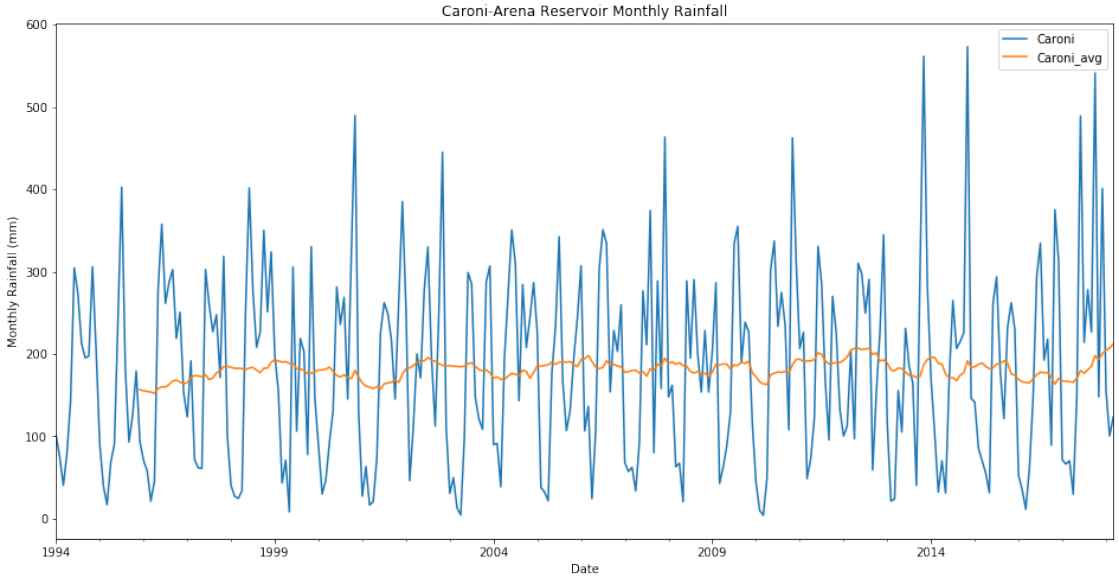
```
In [5]: roll_window = 24
        df['Caroni_avg'] = df['Caroni'].rolling(window=roll_window).mean()
        df['Navet_avg'] = df['Navet'].rolling(window=roll_window).mean()
        df['Hollis_avg'] = df['Hollis'].rolling(window=roll_window).mean()
        df['Hillsborough_avg'] = df['Hillsborough'].rolling(window=roll_window).mean()
        df.head()

Out[5]:              Caroni    Navet      Hollis  Hillsborough  Caroni_avg  Navet_avg  \
        Date
        1994-01-01  101.542  123.155  163.765000       105.881         NaN        NaN
        1994-02-01   75.263   76.695   85.701000        61.204         NaN        NaN
        1994-03-01   40.502   62.063   84.786333        56.863         NaN        NaN
        1994-04-01   79.423   85.095  126.181000        73.508         NaN        NaN
        1994-05-01  143.962  165.100  195.160000       153.434         NaN        NaN

                    Hollis_avg  Hillsborough_avg
        Date
        1994-01-01         NaN               NaN
        1994-02-01         NaN               NaN
```

```
1994-03-01          NaN                 NaN
1994-04-01          NaN                 NaN
1994-05-01          NaN                 NaN
```

5 Data Visualization

```
In [6]: C = df[['Caroni', 'Caroni_avg']].plot(figsize=(16,8), title='Caroni-Arena Reservoir Mo
        C.set_ylabel("Monthly Rainfall (mm)")
```

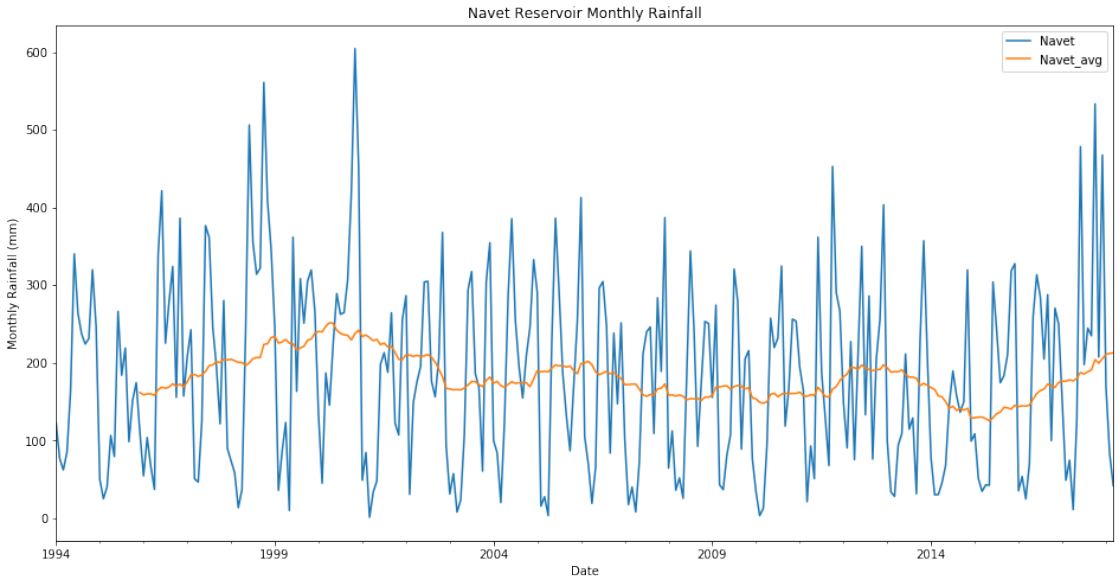
```
Out[6]: <matplotlib.text.Text at 0x7b59cd0>
```



At Caroni-Arena Reservoir, rainfall seems to be pretty constant. 2014 and 2015 in particular saw a lot of rainfall.

```
In [7]: N = df[['Navet', 'Navet_avg']].plot(figsize=(16,8), title='Navet Reservoir Monthly Rai
        N.set_ylabel("Monthly Rainfall (mm)")
```

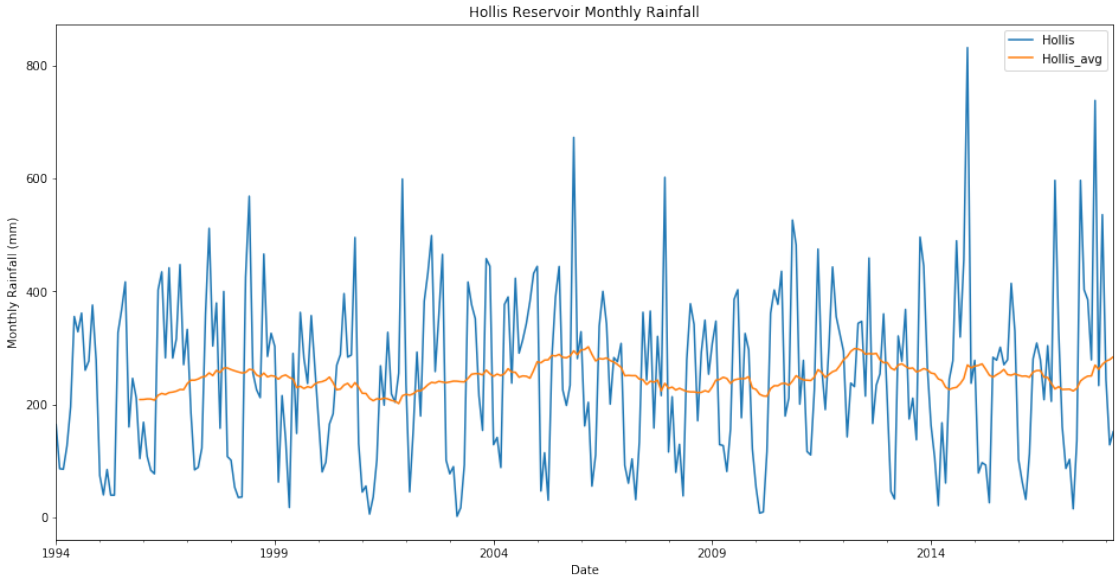
```
Out[7]: <matplotlib.text.Text at 0x7be3430>
```



At Navet Reservoir, no dominant pattern is present on the graph. Heavy rainfall in 1998 and 2001 skews the average upward, while low rainfall between 2014 and 2017 lowered the average.

```
In [8]: Ho = df[['Hollis', 'Hollis_avg']].plot(figsize=(16,8), title='Hollis Reservoir Monthly
        Ho.set_ylabel("Monthly Rainfall (mm)")
```

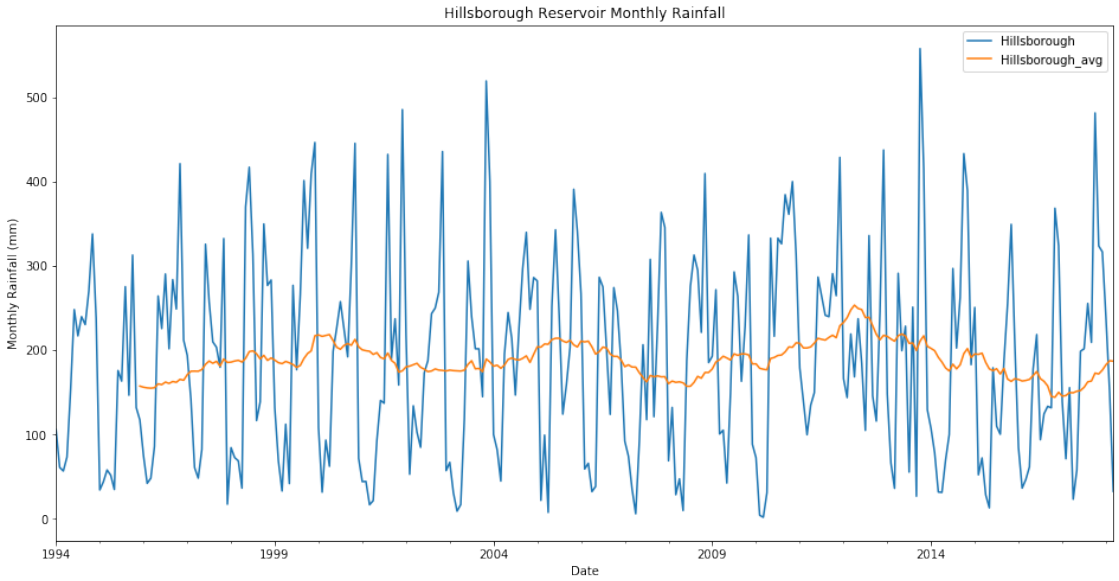
```
Out[8]: <matplotlib.text.Text at 0x7d273f0>
```



At Hollis Reservoir, the appears to be constant. The regular fluctuations in the average line may be caused by the El Nino/ La Nina phenomenon. However after each cycle, the rainfall returns to the same level.

```
In [9]: Hi = df[['Hillsborough', 'Hillsborough_avg']].plot(figsize=(16,8), title='Hillsborough
        Hi.set_ylabel("Monthly Rainfall (mm)")
```

```
Out[9]: <matplotlib.text.Text at 0x816a5b0>
```



At Hillsborough reservoir in Tobago, the rainfall again has a cyclic pattern. From 2013 to 2017 there was a decrease in rainfall but is now looking to head up again, similar to what happend from 2008 to 2013.

6 Annual Rainfall Volumes

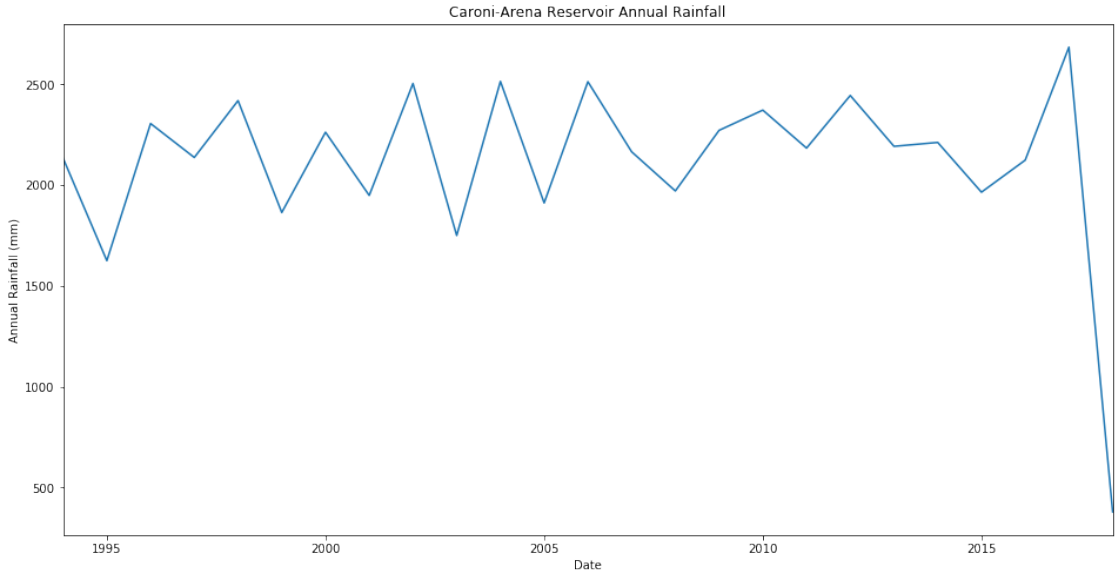
Based on the monthly rainfall data, there is not enough evidence to suggest that rainfall is decreasing. Now we are going to plot the annual rainfall volumes to back up this claim. I'm going to create a new dataframe to hold these values.

```
In [10]: annual_df = df[['Caroni', 'Navet', 'Hollis', 'Hillsborough']].groupby(df.index.year).s
         annual_df.head()
```

```
Out[10]:          Caroni     Navet       Hollis  Hillsborough
         Date
         1994  2133.822  2374.977  2891.354333      2233.217
         1995  1625.910  1505.200  2107.100000      1548.010
         1996  2306.270  2547.460  3311.580000      2400.170
         1997  2137.760  2342.400  3030.070000      2054.950
         1998  2419.900  3235.400  2987.310000      2529.480
```

```
In [11]: C = annual_df['Caroni'].plot(figsize=(16,8), title='Caroni-Arena Reservoir Annual Rai
         C.set_ylabel("Annual Rainfall (mm)")
```

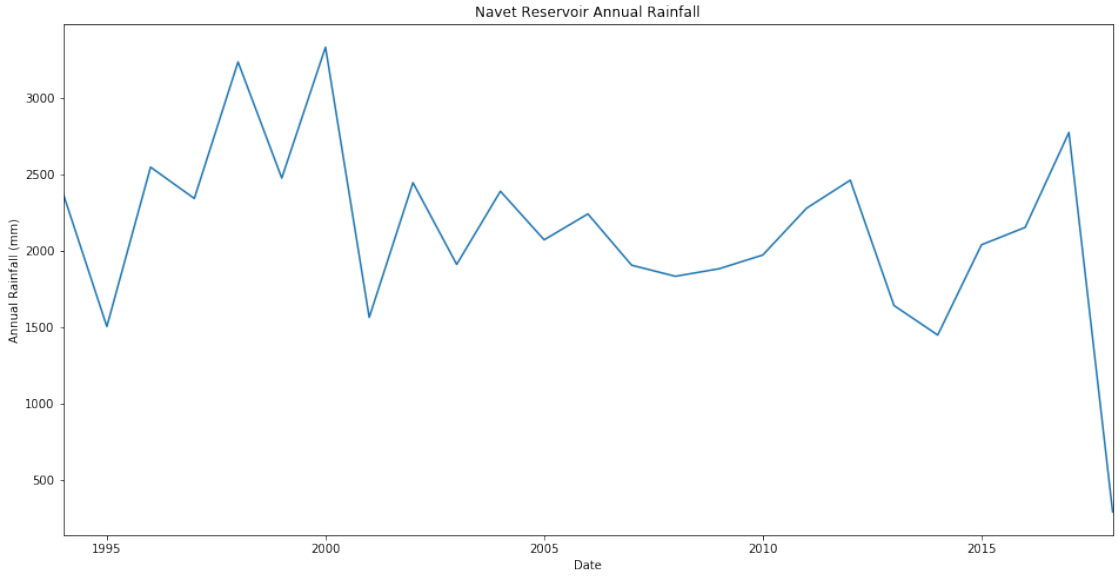
```
Out[11]: <matplotlib.text.Text at 0x8218350>
```



The dip at the end is because all the values for 2018 are not in as yet. But as shown, there are no large deviations from the norm. I suspect this will be true for all of the reservoirs.

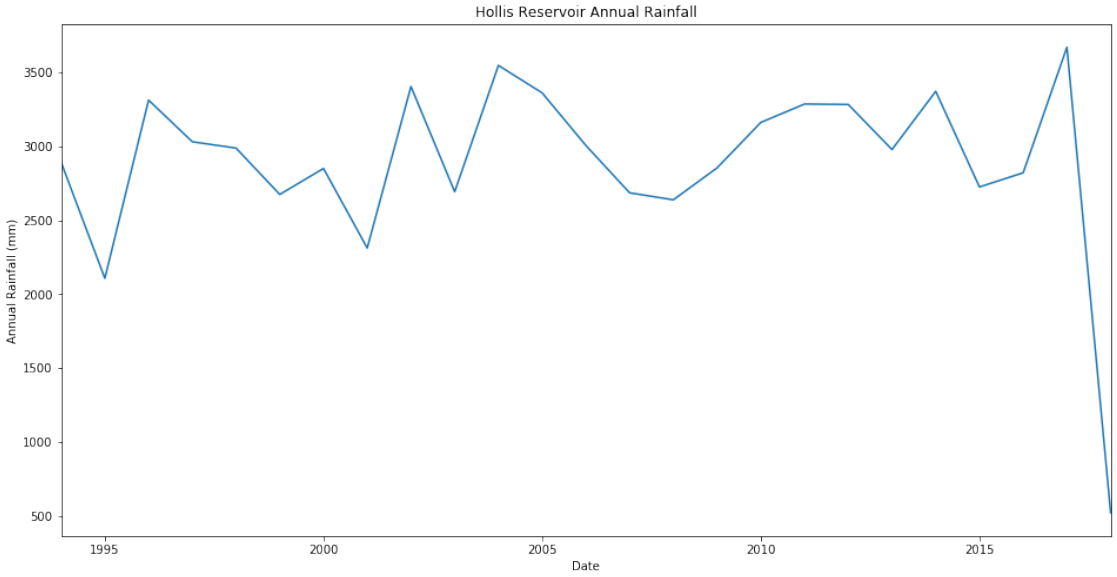
```
In [12]: N = annual_df['Navet'].plot(figsize=(16,8), title='Navet Reservoir Annual Rainfall')
         N.set_ylabel("Annual Rainfall (mm)")
```

```
Out[12]: <matplotlib.text.Text at 0x844f610>
```



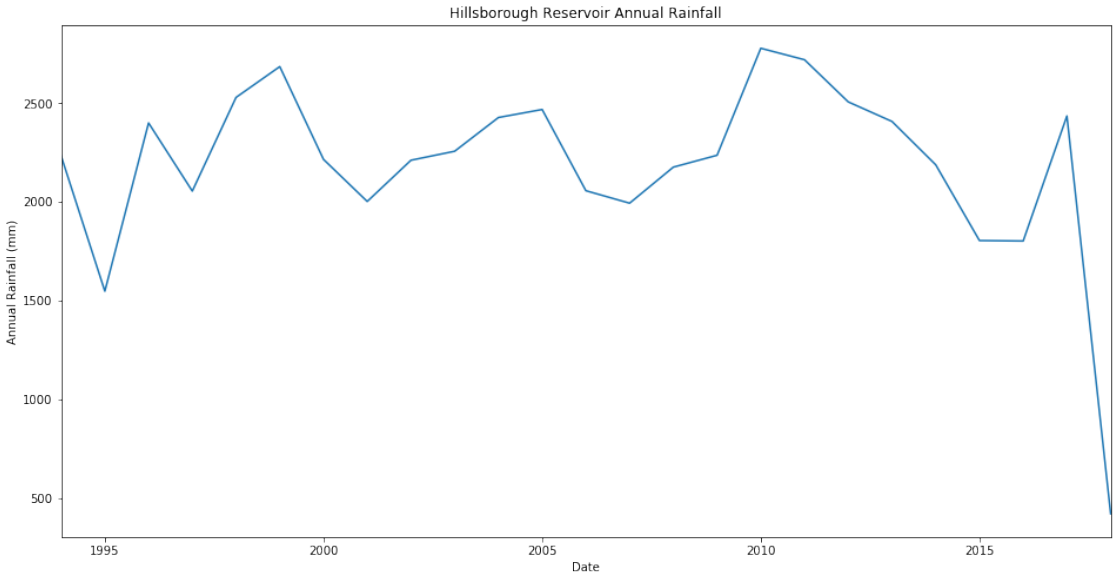
```
In [13]: Ho = annual_df['Hollis'].plot(figsize=(16,8), title='Hollis Reservoir Annual Rainfall
         Ho.set_ylabel("Annual Rainfall (mm)")
```

```
Out[13]: <matplotlib.text.Text at 0x84d79f0>
```




```
In [14]: Hi = annual_df['Hillsborough'].plot(figsize=(16,8), title='Hillsborough Reservoir Annu
         Hi.set_ylabel("Annual Rainfall (mm)")
```

```
Out[14]: <matplotlib.text.Text at 0x84d1d30>
```



Nothing suspicious at Hollis and Hillsborough. This reinforces the idea that there are no significant deviations from the normal rainfall patterns. Everybody is pretty close to that 2000 mm line, except for Hollis who is above.

7 What about max and min values?

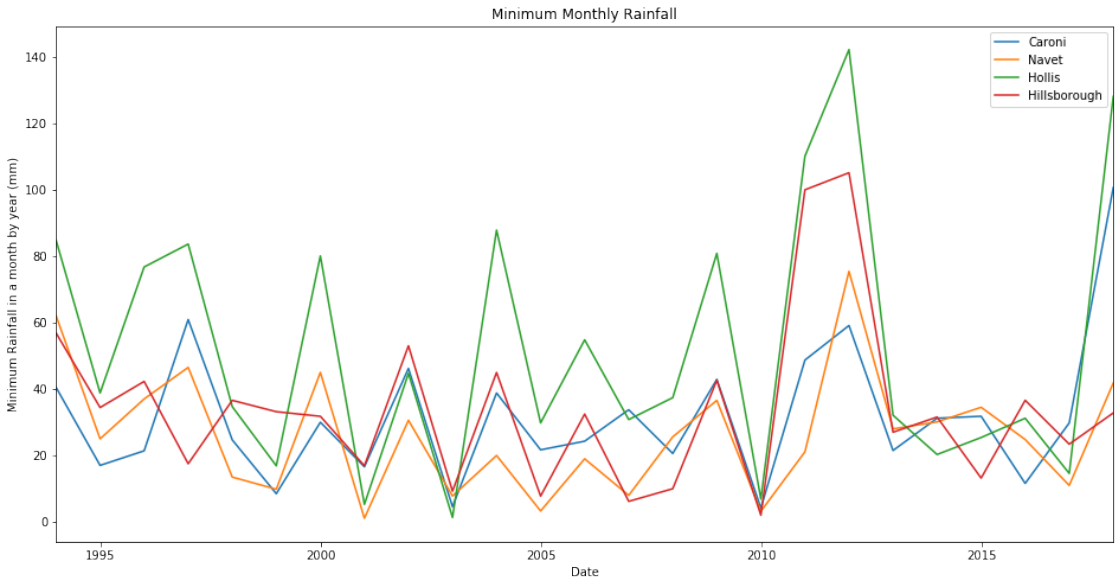
Are those values deviating from the norm? It is possible that the average is not changing, but the max's are getting higher and the min's are getting lower. It doesn't look like that is the case from the graph, but let's plot some more lines just in case. I'm going to create yet another df. Minimum values are more concerning so those are first.

```
In [15]: min_df = df[['Caroni', 'Navet', 'Hollis', 'Hillsborough']].groupby(df.index.year).min
         min_df.head()
```

```
Out[15]:       Caroni   Navet     Hollis  Hillsborough
         Date
         1994  40.502  62.063  84.786333        56.863
         1995  17.020  25.000  38.800000        34.420
         1996  21.400  37.000  76.700000        42.280
         1997  60.900  46.500  83.600000        17.500
         1998  24.700  13.500  34.700000        36.590
```

```
In [16]: A = min_df.plot(figsize=(16,8), title='Minimum Monthly Rainfall')
         A.set_ylabel('Minimum Rainfall in a month by year (mm)')
```

```
Out[16]: <matplotlib.text.Text at 0x873ea10>
```



I've plotted all on the same graph because its all over the place and shows no patterns. Same for the maximum values below.

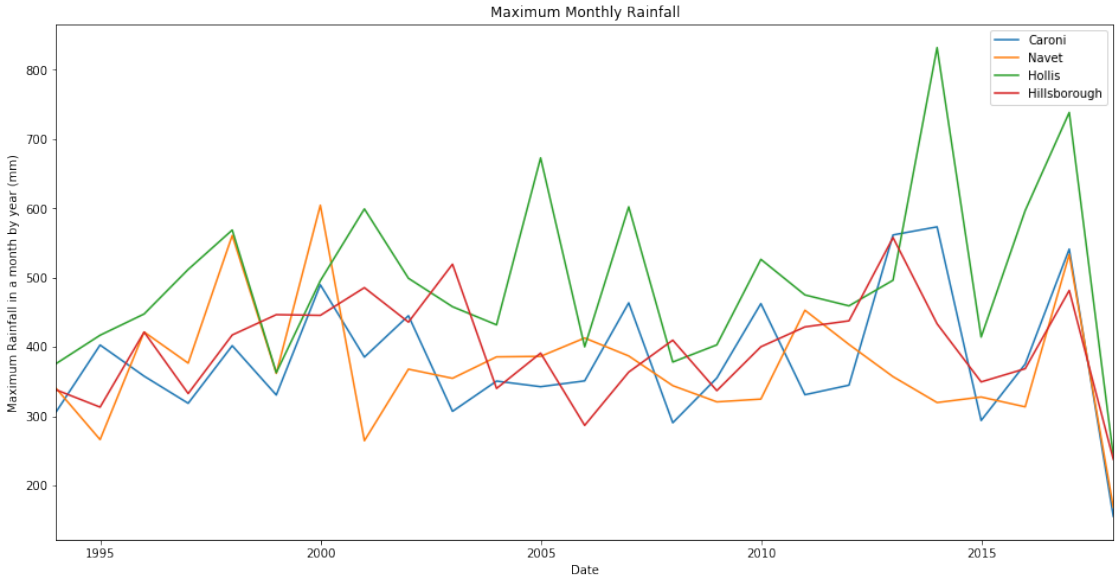
```
In [17]: max_df = df[['Caroni', 'Navet', 'Hollis', 'Hillsborough']].groupby(df.index.year).max
         max_df.head()
```

Out[17]:

Date	Caroni	Navet	Hollis	Hillsborough
1994	305.946	340.233	375.762	338.021
1995	402.700	266.100	416.800	313.000
1996	357.700	421.460	447.500	421.360
1997	318.540	376.500	511.800	332.600
1998	401.700	560.900	568.700	417.180

```
In [18]: A = max_df.plot(figsize=(16,8), title='Maximum Monthly Rainfall')
         A.set_ylabel('Maximum Rainfall in a month by year (mm)')
```

Out[18]: <matplotlib.text.Text at 0x81d3270>



8 Conclusions

Based on this simple study, there is not enough evidence to suggest that rainfall at the major reservoirs across Trinidad and Tobago is decreasing. Then what is the reason for the increasing water woes? Two major reasons are:

1. Increased Demand/ consumption
2. Increased Unaccounted-For-Water

There are probably many other factors that affect water resources throughout the country. That is why an Integrated Water Resources Management approach is recommended. It is also recommended that this study be repeated with a larger dataset. Maybe it is possible that rainfall 50 years was more than what we receive today. Without data I can't backup that claim.