Appendix 3 Exploration and processing of data

```
[57]: import numpy as np import pandas as pd
```

1 Cleaning Data

```
[58]: # Reading orginal dataset into excel file original_df = pd.read_excel('Original-River-Data.xlsx', usecols='A:I', usecol
```

1.0.1 Data Exploration

2.4

76.0

```
[59]: original_df.head(10)
[59]:
        Unnamed: O Crakehill Skip Bridge Westwick Skelton
                                                                 Arkengarthdale \
      0 1993-01-01
                         10.40
                                      4.393
                                                 9.291
                                                          26.1
                                                                             0.0
      1 1993-01-02
                          9.95
                                      4.239
                                                 8.622
                                                          24.86
                                                                             0.0
      2 1993-01-03
                          9.46
                                      4.124
                                                 8.057
                                                          23.6
                                                                             0.0
      3 1993-01-04
                          9.41
                                      4.363
                                                 7.925
                                                         23.47
                                                                             2.4
      4 1993-01-05
                         26.30
                                     11.962
                                                58.704
                                                          60.7
                                                                            11.2
      5 1993-01-06
                         32.10
                                     10.237
                                                34.416
                                                         98.01
                                                                             0.0
      6 1993-01-07
                         19.30
                                      7.254
                                                22.263
                                                         56.99
                                                                             5.6
      7 1993-01-08
                         22.00
                                      7.266
                                                29.587
                                                         56.66
                                                                             1.6
      8 1993-01-09
                         35.50
                                                          78.1
                                                                            14.4
                                      8.153
                                                60.253
      9 1993-01-10
                         51.00
                                     13.276
                                                93.951
                                                         125.7
                                                                            20.8
                                    Snaizeholme
        East Cowton Malham Tarn
                   0
                               0.0
                                             4.0
      0
                   0
                               0.8
                                             0.0
      1
      2
                               0.8
                                             0.0
      3
                24.8
                               0.8
                                           61.6
      4
                 5.6
                              33.6
                                           111.2
      5
                   0
                               1.6
                                             0.8
      6
                   4
                              17.6
                                           36.0
      7
                   0
                               1.6
                                             2.4
                              55.2
      8
                 0.8
                                           104.8
```

```
[60]: original_df.info()
     <class 'pandas.core.frame.DataFrame'>
     RangeIndex: 1461 entries, 0 to 1460
     Data columns (total 9 columns):
          Column
                          Non-Null Count Dtype
          ____
                          _____
      0
          Unnamed: 0
                          1461 non-null
                                           datetime64[ns]
          Crakehill
      1
                          1461 non-null
                                           float64
      2
          Skip Bridge
                          1461 non-null
                                           object
          Westwick
      3
                          1461 non-null
                                           float64
      4
          Skelton
                          1461 non-null
                                           object
          Arkengarthdale 1461 non-null
                                           float64
          East Cowton
                          1461 non-null
                                           object
          Malham Tarn
                          1461 non-null
                                           float64
          Snaizeholme
                          1461 non-null
                                           float64
     dtypes: datetime64[ns](1), float64(5), object(3)
     memory usage: 102.9+ KB
[61]: river_data = original_df.copy()
      river_data.head()
       Unnamed: O Crakehill Skip Bridge Westwick Skelton Arkengarthdale \
[61]:
      0 1993-01-01
                        10.40
                                    4.393
                                              9.291
                                                       26.1
                                                                         0.0
      1 1993-01-02
                         9.95
                                    4.239
                                              8.622
                                                      24.86
                                                                         0.0
      2 1993-01-03
                         9.46
                                    4.124
                                              8.057
                                                       23.6
                                                                         0.0
      3 1993-01-04
                         9.41
                                    4.363
                                              7.925
                                                      23.47
                                                                         2.4
                        26.30
                                                                        11.2
      4 1993-01-05
                                   11.962
                                             58.704
                                                       60.7
       East Cowton Malham Tarn Snaizeholme
                  0
                             0.0
                                          4.0
                             0.8
                                          0.0
      1
                  0
      2
                  0
                             0.8
                                          0.0
      3
               24.8
                             0.8
                                         61.6
                                        111.2
      4
                5.6
                            33.6
[62]: # Renaming Headers
      new_columns = {'Unnamed: 0': 'Date'}
      new_columns.update({col: f"{col} MDF (Cumecs)" for col in river_data.columns[1:
      →5]})
      new_columns.update({col: f"{col} DRT (mm)" for col in river_data.columns[5:]})
      river_data.rename(
          columns=new_columns,
          inplace=True
      river_data.head()
```

```
[62]:
              Date Crakehill MDF (Cumecs) Skip Bridge MDF (Cumecs) \
      0 1993-01-01
                                                                 4.393
                                       10.40
      1 1993-01-02
                                        9.95
                                                                 4.239
      2 1993-01-03
                                       9.46
                                                                 4.124
      3 1993-01-04
                                       9.41
                                                                 4.363
      4 1993-01-05
                                       26.30
                                                                11.962
         Westwick MDF (Cumecs) Skelton MDF (Cumecs)
                                                       Arkengarthdale DRT (mm)
                          9.291
      0
                                                 26.1
                                                                            0.0
      1
                          8.622
                                                24.86
                                                                            0.0
      2
                          8.057
                                                 23.6
                                                                            0.0
      3
                          7.925
                                                23.47
                                                                            2.4
      4
                         58.704
                                                 60.7
                                                                           11.2
                               Malham Tarn DRT (mm)
        East Cowton DRT (mm)
                                                      Snaizeholme DRT (mm)
                            0
                                                 0.0
                                                                        4.0
      0
      1
                            0
                                                 0.8
                                                                        0.0
      2
                            0
                                                 0.8
                                                                        0.0
      3
                                                 0.8
                         24.8
                                                                       61.6
      4
                          5.6
                                                33.6
                                                                      111.2
     MDF - Mean Daily Flow
     DRT - Daily Rainfall Total
[63]: river_data.info()
     <class 'pandas.core.frame.DataFrame'>
```

RangeIndex: 1461 entries, 0 to 1460

Data columns (total 9 columns):

```
Column
                              Non-Null Count Dtype
    _____
                              _____
 0
    Date
                              1461 non-null
                                              datetime64[ns]
    Crakehill MDF (Cumecs)
 1
                              1461 non-null
                                              float64
 2
    Skip Bridge MDF (Cumecs) 1461 non-null
                                              object
    Westwick MDF (Cumecs)
 3
                              1461 non-null
                                              float64
 4
    Skelton MDF (Cumecs)
                              1461 non-null
                                              object
 5
    Arkengarthdale DRT (mm)
                              1461 non-null
                                              float64
    East Cowton DRT (mm)
                              1461 non-null
                                              object
    Malham Tarn DRT (mm)
                              1461 non-null
                                              float64
    Snaizeholme DRT (mm)
                              1461 non-null
                                              float64
dtypes: datetime64[ns](1), float64(5), object(3)
memory usage: 102.9+ KB
```

```
[64]: # Converting to non-numeric columns to numeric columns
      river_data['Skip Bridge MDF (Cumecs)'] = pd.to_numeric(river_data['Skip Bridge_
      →MDF (Cumecs)'], errors='coerce')
```

```
river_data['Skelton MDF (Cumecs)'] = pd.to_numeric(river_data['Skelton MDF_L
      river_data['East Cowton DRT (mm)'] = pd.to_numeric(river_data['East Cowton DRT_u
      river_data['Date'] = pd.to_datetime(river_data['Date'], errors='coerce')
     river_data.info()
     <class 'pandas.core.frame.DataFrame'>
     RangeIndex: 1461 entries, 0 to 1460
     Data columns (total 9 columns):
          Column
                                   Non-Null Count
                                                   Dtype
          _____
                                   _____
      0
          Date
                                   1461 non-null
                                                   datetime64[ns]
      1
          Crakehill MDF (Cumecs)
                                   1461 non-null
                                                   float64
      2
          Skip Bridge MDF (Cumecs)
                                   1460 non-null
                                                   float64
          Westwick MDF (Cumecs)
      3
                                   1461 non-null
                                                   float64
      4
          Skelton MDF (Cumecs)
                                   1460 non-null
                                                   float64
      5
          Arkengarthdale DRT (mm)
                                   1461 non-null
                                                   float64
      6
          East Cowton DRT (mm)
                                   1460 non-null
                                                   float64
      7
          Malham Tarn DRT (mm)
                                   1461 non-null
                                                   float64
          Snaizeholme DRT (mm)
                                   1461 non-null
                                                   float64
     dtypes: datetime64[ns](1), float64(8)
     memory usage: 102.9 KB
[65]: river_data.isna().sum()
[65]: Date
                                 0
     Crakehill MDF (Cumecs)
                                 0
     Skip Bridge MDF (Cumecs)
     Westwick MDF (Cumecs)
                                 0
     Skelton MDF (Cumecs)
                                 1
     Arkengarthdale DRT (mm)
                                 0
     East Cowton DRT (mm)
                                 1
     Malham Tarn DRT (mm)
                                 0
     Snaizeholme DRT (mm)
                                 0
     dtype: int64
[66]: river_data.describe()
[66]:
            Crakehill MDF (Cumecs)
                                    Skip Bridge MDF (Cumecs)
                       1461.000000
     count
                                                 1460.000000
                         17.519213
                                                    6.929692
     mean
     std
                         52.587125
                                                   28.182097
     min
                       -999.000000
                                                 -999.000000
     25%
                          5.220000
                                                    2.166000
     50%
                         10.100000
                                                    3.494500
                         21.900000
     75%
                                                    8.892250
                        220.000000
                                                   80.244000
     max
```

```
Westwick MDF (Cumecs)
                                     Skelton MDF (Cumecs)
                                                            Arkengarthdale DRT (mm)
      count
                         1461.00000
                                               1460.000000
                                                                         1461.000000
                           21.59704
                                                 47.093886
                                                                            8.519233
      mean
                           28.35579
                                                 55.712853
                                                                          133.950452
      std
      min
                            1.95400
                                                  3.694000
                                                                         -999.000000
      25%
                                                 12.442500
                                                                            0.000000
                            5.67300
      50%
                           10.39100
                                                 24.260000
                                                                            0.800000
      75%
                           26.73600
                                                 59.357500
                                                                            6.400000
                          374.06100
                                                448.100000
                                                                         5000.000000
      max
             East Cowton DRT (mm)
                                    Malham Tarn DRT (mm)
                                                           Snaizeholme DRT (mm)
      count
                       1460.000000
                                              1461.000000
                                                                     1461.000000
                         11.466301
                                                68.896920
                                                                        9.725394
      mean
      std
                        235.722765
                                              2092.760651
                                                                       20.984849
      min
                          0.000000
                                                 0.000000
                                                                        0.000000
      25%
                          0.000000
                                                 0.00000
                                                                        0.00000
      50%
                          0.000000
                                                 1.600000
                                                                        0.800000
      75%
                          5.600000
                                                18.400000
                                                                       10.400000
                       9000.000000
                                             80000,000000
                                                                      268.800000
      max
     1.0.2 Removing Outliers and Null Values
[67]: # Dropping nulll values
      flow_cols = list(river_data.columns[1:5])
      rain_cols = list(river_data.columns[5:])
      null_values = river_data.isna().any(axis=1)
      river_data[null_values] # Rows with at least 1 null value
[67]:
                 Date
                       Crakehill MDF (Cumecs)
                                                 Skip Bridge MDF (Cumecs)
      96
           1993-04-07
                                           22.9
                                                                     4.159
           1995-03-01
                                                                    19.096
      789
                                          80.6
                                           12.7
      1134 1996-02-09
                                                                       NaN
            Westwick MDF (Cumecs)
                                    Skelton MDF (Cumecs)
                                                           Arkengarthdale DRT (mm)
      96
                            26,603
                                                      NaN
                                                                                2.4
      789
                           100.761
                                                   174.00
                                                                               17.6
      1134
                             7.576
                                                    20.58
                                                                                0.0
            East Cowton DRT (mm)
                                   Malham Tarn DRT (mm)
                                                          Snaizeholme DRT (mm)
      96
                              0.0
                                                     0.0
                                                                            3.2
      789
                              NaN
                                                    51.2
                                                                           21.6
      1134
                             37.6
                                                    12.0
                                                                           14.4
[68]: river_data.dropna(how="any", inplace=True)
      river_data[null_values]
```

/Users/bhekimaenetja/opt/anaconda3/lib/python3.7/site-packages/ipykernel_launcher.py:2: UserWarning: Boolean Series key will be reindexed to match DataFrame index.

[68]: Empty DataFrame

Columns: [Date, Crakehill MDF (Cumecs), Skip Bridge MDF (Cumecs), Westwick MDF (Cumecs), Skelton MDF (Cumecs), Arkengarthdale DRT (mm), East Cowton DRT (mm), Malham Tarn DRT (mm), Snaizeholme DRT (mm)]

Index: []

[69]: # Replacing negative values
river_data[(river_data[flow_cols + rain_cols] < 0).any(1)] # replace all_
negative values with zero

[69]:		Date	Crakehill MDF (Cumecs)	Skip Bridge MDF	(Cumecs)	\
	43	1993-02-13	-999.00		5.476	
	73	1993-03-15	-999.00		2.546	
	74	1993-03-16	-999.00		2.494	
	116	1993-04-27	24.40		11.684	
	1203	1996-04-18	7.61		-999.000	

	Westwick MDF	(Cumecs)	Skelton MDF	(Cumecs)	Arkengarthdale DRT	(mm)	\
43		11.051		30.73		0.0	
73		7.179		18.06		11.2	
74		7.232		17.16		0.8	
116		22.181		73.96	_	999.0	
120	3	13.918		16.84		0.8	

	East Cowton DRT (mm)	Malham Tarn DRT (mm)	Snaizeholme DRT (mm)
43	0.0	0.0	0.0
73	0.0	86.0	19.2
74	0.0	12.8	8.0
116	0.0	0.0	0.0
1203	4.8	47.2	32.0

[70]: river_data[flow_cols+rain_cols] = river_data[flow_cols+rain_cols].

where((river_data[flow_cols+rain_cols] > -1), 0)
river_data[(river_data[flow_cols + rain_cols] < 0).any(1)]

[70]: Empty DataFrame

Columns: [Date, Crakehill MDF (Cumecs), Skip Bridge MDF (Cumecs), Westwick MDF (Cumecs), Skelton MDF (Cumecs), Arkengarthdale DRT (mm), East Cowton DRT (mm), Malham Tarn DRT (mm), Snaizeholme DRT (mm)]

Index: []

[71]: # Dropping rows with rainfall outliers
rainfall_outliers = river_data[(river_data[rain_cols] > 400).any(1)]

	rainf	fall_outlier	rs .					
[71]:		Date 1995-02-11 1995-02-28 1996-01-10	Crakehill	MDF (Cumecs) 65.0 44.6 32.4	Skip Bric	dge MDF (Cumecs) 31.496 11.563 10.548	\	
		Westwick M	IDF (Cumecs)	Skelton MDF		Arkengarthdale	DRT (mm)	\
	771		108.575		136.70		5000.0	
	788		52.105		93.91		19.2	
	1104		30.086		84.33		0.8	
		East Cowto	on DRT (mm)	Malham Tarn	DRT (mm)	Snaizeholme DRT	(mm)	
	771		15.2		108.4		80.8	
	788		9000.0		46.4		47.2	
	1104		0.0		80000.0		0.8	
[72]:	river	_	_	tliers.index, _cols] > 400)	-	[rue) # drop rows that	have rain	ıfall <mark>u</mark>
[70]	Empty	7 DataFrame						MDE
[73]:	(Cume Malha Index	ecs), Skelto am Tarn DRT a: [] opping rows	on MDF (Cume (mm), Snaiz with river ers = river	cs), Arkengar eholme DRT (m	thdale DRI	ge MDF (Cumecs), [(mm), East Cowt cols] == 0).any	con DRT (m	
	(Cume Malha Index	ecs), Skelto mm Tarn DRT c: [] ppping rows c_flow_outli	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m	thdale DRI m)] data[flow]	(mm), East Cowt	con DRT (m	
[73]:	(Cume Malha Index	ecs), Skelto am Tarn DRT a: [] apping rows a_flow_outli a_flow_outli	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m flow outliers _data[(river_	thdale DRI m)] data[flow]	cols] == 0).any	con DRT (m	
[73]:	(Cume Malha Index river river 43	ecs), Skelto am Tarn DRT a: [] apping rows a_flow_outli a_flow_outli Date	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m flow outliers _data[(river_	thdale DRI m)] data[flow]	cols] == 0).any	con DRT (m	
[73]:	(Cume Malha Index river river 43	ecs), Skeltom Tarn DRT c: [] copping rows c_flow_outli c_flow_outli Date 1993-02-13	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs) 0.00	thdale DRI m)] data[flow]	cols] == 0).any	con DRT (m	
[73]:	(Cume Malha Index # Dro river river 43 73 74	ecs), Skelto am Tarn DRT a: [] opping rows a_flow_outli a_flow_outli Date 1993-02-13 1993-03-15	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRI m)] data[flow]	cols] == 0).any dge MDF (Cumecs) 5.476 2.546	con DRT (m	
[73]:	(Cume Malha Index # Dro river river 43 73 74	pecs), Skeltom Tarn DRT c: [] ppping rows c_flow_outli c_flow_outli 1993-02-13 1993-03-15 1993-03-16 1996-04-18	on MDF (Cume (mm), Snaiz with river ers = river ers	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow]	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	(1)]	m),
[73]:	(Cume Malha Index # Dro river river 43 73 74	pecs), Skeltom Tarn DRT c: [] ppping rows c_flow_outli c_flow_outli 1993-02-13 1993-03-15 1993-03-16 1996-04-18	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow]	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	(1)]	m),
[73]:	(Cume Malha Index # Dro river river 43 73 74 1203	pecs), Skeltom Tarn DRT c: [] ppping rows c_flow_outli c_flow_outli 1993-02-13 1993-03-15 1993-03-16 1996-04-18	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow_Skip Bride (Cumecs)	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	CON DRT (m (1)]	m),
[73]:	(Cume Malha Index river river 43 74 1203	pecs), Skeltom Tarn DRT c: [] ppping rows c_flow_outli c_flow_outli 1993-02-13 1993-03-15 1993-03-16 1996-04-18	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill DF (Cumecs) 11.051	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow] Skip Brid (Cumecs) 30.73	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	DRT (mm) 0.0	m),
[73]:	(Cume Malha Index # Dro river river 43 73 74 1203	pecs), Skeltom Tarn DRT c: [] ppping rows c_flow_outli c_flow_outli 1993-02-13 1993-03-15 1993-03-16 1996-04-18	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill IDF (Cumecs) 11.051 7.179	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DR7 m)] data[flow] Skip Brid (Cumecs) 30.73 18.06	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	DRT (mm) 0.0 11.2	m),
[73]:	(Cume Malha Index # Dro river river 43 73 74 1203	pring rows cflow_outli Date 1993-02-13 1993-03-15 1993-04-18 Westwick M	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill IDF (Cumecs) 11.051 7.179 7.232	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow] Skip Brid (Cumecs) 30.73 18.06 17.16 16.84	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000	DRT (mm) 0.0 11.2 0.8 0.8	m),
[73]:	(Cume Malha Index # Dro river river 43 73 74 1203	pring rows cflow_outli Date 1993-02-13 1993-03-15 1993-04-18 Westwick M	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill DF (Cumecs) 11.051 7.179 7.232 13.918	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRIm)] data[flow] Skip Brid (Cumecs) 30.73 18.06 17.16 16.84	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000 Arkengarthdale	DRT (mm) 0.0 11.2 0.8 0.8	m),
[73]:	(Cume Malha Index Index 1	pring rows cflow_outli Date 1993-02-13 1993-03-15 1993-04-18 Westwick M	on MDF (Cume (mm), Snaiz with river ers = river ers Crakehill MDF (Cumecs) 11.051 7.179 7.232 13.918 on DRT (mm)	cs), Arkengar eholme DRT (m flow outliers _data[(river_ MDF (Cumecs)	thdale DRTm)] data[flow] Skip Brid (Cumecs) 30.73 18.06 17.16 16.84 DRT (mm)	cols] == 0).any dge MDF (Cumecs) 5.476 2.546 2.494 0.000 Arkengarthdale	DRT (mm) 0.0 11.2 0.8 0.8 (mm)	m),

1203 4.8 47.2 32.0

[74]: river_data.drop(river_flow_outliers.index, inplace=True)
river_data[(river_data[flow_cols] == 0).any(1)]

[74]: Empty DataFrame

Columns: [Date, Crakehill MDF (Cumecs), Skip Bridge MDF (Cumecs), Westwick MDF (Cumecs), Skelton MDF (Cumecs), Arkengarthdale DRT (mm), East Cowton DRT (mm), Malham Tarn DRT (mm), Snaizeholme DRT (mm)]

Index: []

75%

max

[75]: river_data.describe()

	_				
[75]:		Crakehill MDF (Cumecs)	Skip Bridge MDF (Cum	necs) \	
	count	1451.000000	1451.00	00000	
	mean	19.522233	7.60	00946	
	std	25.249077	10.01	13759	
	min	2.060000	1.00	02000	
	25%	5.240000	2.15	58500	
	50%	10.100000	3.49	92000	
	75%	21.750000	8.83	33000	
	max	220.000000	80.24	14000	
		Westwick MDF (Cumecs)	Skelton MDF (Cumecs)	Arkengarthdale DRT (mm) \	
	count	1451.000000	1451.000000	1451.000000	
	mean	21.494272	46.977784	5.784149	
	std	28.263025	55.691669	13.262708	
	min	1.954000	3.694000	0.000000	
	25%	5.632500	12.385000	0.00000	
	50%	10.379000	24.250000	0.800000	
	75%	26.652000	59.150000	6.400000	
	max	374.061000	448.100000	225.200000	
		East Cowton DRT (mm)	Malham Tarn DRT (mm)	Snaizeholme DRT (mm)	
	count	1451.000000	1451.000000	1451.000000	
	mean	5.295107	13.986492	9.635837	
	std	12.296973	25.045850	20.934958	
	min	0.000000	0.000000	0.000000	
	25%	0.000000	0.000000	0.00000	
	50%	0.000000	1.600000	0.800000	

5.600000

165.600000

18.400000

252.000000

10.400000

1.0.3 Exporting Cleaned Data Set

```
[76]: export_data = river_data.copy()
export_data["Date"] = export_data["Date"].astype("string")
export_data.to_excel('River-Data-Cleaned.xlsx')
```

2 Lagging and Moving Averages

```
[77]: clean_df = pd.read_excel('River-Data-Cleaned.xlsx')
      clean_df.drop(["Unnamed: 0"], axis=1, inplace=True)
      clean df.head(10)
[77]:
                                                Skip Bridge MDF (Cumecs)
                Date
                      Crakehill MDF (Cumecs)
         1993-01-01
                                         10.40
                                                                    4.393
        1993-01-02
                                         9.95
                                                                    4.239
      2 1993-01-03
                                         9.46
                                                                    4.124
      3 1993-01-04
                                         9.41
                                                                    4.363
                                        26.30
      4 1993-01-05
                                                                   11.962
      5 1993-01-06
                                        32.10
                                                                   10.237
                                                                    7.254
      6 1993-01-07
                                         19.30
      7 1993-01-08
                                        22.00
                                                                    7.266
      8 1993-01-09
                                        35.50
                                                                    8.153
      9 1993-01-10
                                        51.00
                                                                   13.276
         Westwick MDF (Cumecs) Skelton MDF (Cumecs)
                                                         Arkengarthdale DRT (mm)
      0
                          9.291
                                                  26.10
                                                                               0.0
                          8.622
                                                  24.86
                                                                               0.0
      1
                          8.057
      2
                                                  23.60
                                                                               0.0
      3
                          7.925
                                                  23.47
                                                                               2.4
      4
                         58.704
                                                  60.70
                                                                              11.2
      5
                         34.416
                                                  98.01
                                                                               0.0
      6
                         22.263
                                                  56.99
                                                                               5.6
      7
                         29.587
                                                  56.66
                                                                               1.6
      8
                         60.253
                                                  78.10
                                                                              14.4
      9
                         93.951
                                                 125.70
                                                                              20.8
         East Cowton DRT (mm)
                                 Malham Tarn DRT (mm)
                                                         Snaizeholme DRT (mm)
      0
                            0.0
                                                   0.0
                                                                           4.0
      1
                            0.0
                                                   0.8
                                                                           0.0
      2
                           0.0
                                                   0.8
                                                                           0.0
                          24.8
      3
                                                   0.8
                                                                          61.6
      4
                           5.6
                                                  33.6
                                                                         111.2
                           0.0
      5
                                                   1.6
                                                                           0.8
                           4.0
      6
                                                  17.6
                                                                          36.0
      7
                           0.0
                                                                           2.4
                                                   1.6
                           0.8
      8
                                                  55.2
                                                                         104.8
      9
                            2.4
                                                  76.0
                                                                         136.8
```

[78]: clean_df.describe() [78]: Crakehill MDF (Cumecs) Skip Bridge MDF (Cumecs) count. 1451.000000 1451.000000 7.600946 19.522233 mean std 25.249077 10.013759 min 2.060000 1.002000 25% 5.240000 2.158500 50% 10.100000 3.492000 75% 21.750000 8.833000 220.000000 80.244000 maxWestwick MDF (Cumecs) Skelton MDF (Cumecs) Arkengarthdale DRT (mm) 1451.000000 1451.000000 1451.000000 count 21.494272 46.977784 5.784149 mean std 28.263025 55.691669 13.262708 min 1.954000 3.694000 0.000000 25% 5.632500 12.385000 0.00000 50% 10.379000 24.250000 0.800000 75% 26.652000 59.150000 6.400000 374.061000 448.100000 225.200000 maxEast Cowton DRT (mm) Malham Tarn DRT (mm) Snaizeholme DRT (mm) 1451.000000 1451.000000 1451.000000 count mean 5.295107 13.986492 9.635837 std 12.296973 25.045850 20.934958 0.000000 0.000000 0.000000 min 25% 0.000000 0.00000 0.00000 50% 0.000000 1.600000 0.800000 75% 5.600000 18.400000 10.400000 max 165.600000 252,000000 268.800000 [79]: clean_df.info() <class 'pandas.core.frame.DataFrame'> RangeIndex: 1451 entries, 0 to 1450 Data columns (total 9 columns): # Column Dtype Non-Null Count _____ _____ 0 Date 1451 non-null object 1 Crakehill MDF (Cumecs) 1451 non-null float64 2 Skip Bridge MDF (Cumecs) 1451 non-null float64

1451 non-null

1451 non-null

1451 non-null

1451 non-null

1451 non-null

1451 non-null

float64

float64

float64

float64

float64

float64

3

4

5

6

7

8

Westwick MDF (Cumecs)

Arkengarthdale DRT (mm)

Skelton MDF (Cumecs)

East Cowton DRT (mm)

Malham Tarn DRT (mm)

Snaizeholme DRT (mm)

```
dtypes: float64(8), object(1)
memory usage: 102.1+ KB
```

2.0.1 Lagging Data

```
[80]: lagged df = pd.DataFrame()
      lagged_df["Date"] = clean_df["Date"]
      lagged df[flow cols[-1]] = clean df[flow cols[-1]]
      lagged_df.head(10)
[80]:
               Date Skelton MDF (Cumecs)
      0 1993-01-01
                                    26.10
      1 1993-01-02
                                    24.86
      2 1993-01-03
                                    23.60
      3 1993-01-04
                                    23.47
      4 1993-01-05
                                    60.70
      5 1993-01-06
                                    98.01
      6 1993-01-07
                                    56.99
      7 1993-01-08
                                    56.66
      8 1993-01-09
                                    78.10
      9 1993-01-10
                                   125.70
[81]: # Lagging rainfall and flow columns by 1 to 3 days
      for i in range(3):
          for col in flow_cols:
              col_name = col.replace("(Cumecs)", f"(t-{i+1})")
              lagged_df[col_name] = clean_df[col].shift(i+1)
      for i in range(3):
          for col in rain_cols:
              col_name = col.replace("(mm)", f"(t-{i+1})")
              lagged_df[col_name] = clean_df[col].shift(i+1)
      lagged_df.head(10)
[81]:
               Date Skelton MDF (Cumecs) Crakehill MDF (t-1) \
      0 1993-01-01
                                    26.10
                                                           NaN
      1 1993-01-02
                                    24.86
                                                         10.40
      2 1993-01-03
                                    23.60
                                                          9.95
      3 1993-01-04
                                    23.47
                                                          9.46
      4 1993-01-05
                                    60.70
                                                          9.41
                                                         26.30
      5 1993-01-06
                                    98.01
      6 1993-01-07
                                    56.99
                                                         32.10
                                                         19.30
      7 1993-01-08
                                    56.66
      8 1993-01-09
                                    78.10
                                                         22.00
      9 1993-01-10
                                   125.70
                                                         35.50
```

Skip Bridge MDF (t-1) Westwick MDF (t-1) Skelton MDF (t-1) \

```
0
                       NaN
                                             NaN
                                                                  NaN
1
                    4.393
                                          9.291
                                                                26.10
2
                    4.239
                                          8.622
                                                                24.86
3
                    4.124
                                          8.057
                                                                23.60
4
                    4.363
                                          7.925
                                                                23.47
5
                   11.962
                                         58.704
                                                                60.70
6
                    10.237
                                         34.416
                                                                98.01
7
                    7.254
                                         22.263
                                                                56.99
8
                    7.266
                                         29.587
                                                                56.66
9
                    8.153
                                         60.253
                                                                78.10
   Crakehill MDF (t-2)
                          Skip Bridge MDF (t-2)
                                                   Westwick MDF (t-2)
0
                    NaN
                                              NaN
                                                                    NaN
1
                    NaN
                                              NaN
                                                                    NaN
2
                  10.40
                                            4.393
                                                                  9.291
                   9.95
                                            4.239
3
                                                                  8.622
4
                   9.46
                                            4.124
                                                                  8.057
5
                   9.41
                                            4.363
                                                                  7.925
6
                  26.30
                                           11.962
                                                                 58.704
7
                  32.10
                                           10.237
                                                                 34.416
8
                  19.30
                                            7.254
                                                                 22.263
9
                  22.00
                                            7.266
                                                                 29.587
   Skelton MDF (t-2)
                           Malham Tarn DRT (t-1)
                                                    Snaizeholme DRT (t-1)
0
                  NaN
                                               NaN
                                                                        NaN
                                                                        4.0
                                               0.0
1
                  NaN
2
                26.10
                                               0.8
                                                                        0.0
3
                24.86
                                               0.8
                                                                        0.0
4
                                                                       61.6
                23.60
                                               0.8
                23.47
                                              33.6
                                                                      111.2
5
6
                60.70
                                              1.6
                                                                        0.8
7
                98.01
                                              17.6
                                                                       36.0
                                                                        2.4
8
                56.99
                                              1.6
9
                56.66
                                              55.2
                                                                      104.8
   Arkengarthdale DRT (t-2)
                               East Cowton DRT (t-2)
                                                         Malham Tarn DRT (t-2)
0
                          NaN
                                                   NaN
                                                                             NaN
1
                          NaN
                                                   NaN
                                                                             NaN
2
                          0.0
                                                   0.0
                                                                             0.0
3
                          0.0
                                                   0.0
                                                                             0.8
4
                          0.0
                                                   0.0
                                                                             0.8
5
                          2.4
                                                  24.8
                                                                             0.8
                         11.2
6
                                                   5.6
                                                                            33.6
7
                          0.0
                                                   0.0
                                                                             1.6
                                                   4.0
8
                          5.6
                                                                            17.6
9
                          1.6
                                                   0.0
                                                                             1.6
```

```
0
                            NaN
                                                        NaN
                                                                                NaN
      1
                            NaN
                                                        NaN
                                                                                NaN
      2
                            4.0
                                                        NaN
                                                                                NaN
      3
                            0.0
                                                        0.0
                                                                                0.0
      4
                            0.0
                                                        0.0
                                                                                0.0
      5
                           61.6
                                                        0.0
                                                                                0.0
      6
                          111.2
                                                        2.4
                                                                               24.8
      7
                                                       11.2
                                                                                5.6
                            0.8
      8
                           36.0
                                                        0.0
                                                                                0.0
      9
                            2.4
                                                        5.6
                                                                                4.0
         Malham Tarn DRT (t-3)
                                 Snaizeholme DRT (t-3)
      0
                            NaN
                                                     NaN
      1
                            NaN
                                                     NaN
      2
                            NaN
                                                    NaN
      3
                            0.0
                                                     4.0
      4
                            0.8
                                                    0.0
      5
                            0.8
                                                    0.0
      6
                            0.8
                                                   61.6
      7
                           33.6
                                                   111.2
      8
                            1.6
                                                    0.8
      9
                           17.6
                                                   36.0
      [10 rows x 26 columns]
[82]: # Dropping rows with null values
      lagged_df[lagged_df.isna().any(axis=1)]
[82]:
               Date Skelton MDF (Cumecs)
                                             Crakehill MDF (t-1) \
      0 1993-01-01
                                      26.10
                                                              NaN
      1 1993-01-02
                                      24.86
                                                            10.40
      2 1993-01-03
                                      23.60
                                                             9.95
         Skip Bridge MDF (t-1) Westwick MDF (t-1) Skelton MDF (t-1) \
      0
                            NaN
                                                 NaN
                                                                      NaN
      1
                          4.393
                                               9.291
                                                                   26.10
      2
                          4.239
                                               8.622
                                                                   24.86
         Crakehill MDF (t-2) Skip Bridge MDF (t-2)
                                                       Westwick MDF (t-2)
      0
                          NaN
                                                  NaN
                                                                        NaN
      1
                          NaN
                                                  NaN
                                                                        NaN
      2
                         10.4
                                                4.393
                                                                      9.291
         Skelton MDF (t-2) ... Malham Tarn DRT (t-1)
                                                         Snaizeholme DRT (t-1) \
      0
                        NaN ...
                                                   NaN
                                                                            NaN
      1
                        NaN ...
                                                   0.0
                                                                            4.0
```

Snaizeholme DRT (t-2) Arkengarthdale DRT (t-3) East Cowton DRT (t-3) \

2 26.1 ... 0.8 0.0

0 1 2	Arkengarthdale I	Na Na	2) East Cowton DRT aN aN .0	(t-2) NaN NaN 0.0	Malham Tarn DRT	(t-2) NaN NaN 0.0	\
0 1 2	Snaizeholme DRT	(t-2) NaN NaN 4.0	Arkengarthdale DRT	(t-3) NaN NaN NaN	East Cowton DRT	(t-3) NaN NaN NaN	\
0 1 2	Malham Tarn DRT	(t-3) NaN NaN NaN]	-3) NaN NaN NaN			
г.	22	-					

[3 rows x 26 columns]

[83]: lagged_df.dropna(how="any", inplace=True) lagged_df[lagged_df.isna().any(axis=1)]

[83]: Empty DataFrame

Columns: [Date, Skelton MDF (Cumecs), Crakehill MDF (t-1), Skip Bridge MDF (t-1), Westwick MDF (t-1), Skelton MDF (t-1), Crakehill MDF (t-2), Skip Bridge MDF (t-2), Westwick MDF (t-2), Skelton MDF (t-2), Crakehill MDF (t-3), Skip Bridge MDF (t-3), Westwick MDF (t-3), Skelton MDF (t-3), Arkengarthdale DRT (t-1), East Cowton DRT (t-1), Malham Tarn DRT (t-1), Snaizeholme DRT (t-1), Arkengarthdale DRT (t-2), East Cowton DRT (t-2), Malham Tarn DRT (t-2), Snaizeholme DRT (t-2), Arkengarthdale DRT (t-3), East Cowton DRT (t-3), Malham Tarn DRT (t-3), Snaizeholme DRT (t-3)] Index: []

[0 rows x 26 columns]

[84]: lagged_df.describe()

[84]:	Skelton MDF (Cumecs)	Crakehill MDF (t-1)	Skip Bridge MDF (t-1)	\
count	1448.000000	1448.000000	1448.000000	
mean	47.023622	19.537023	7.606707	
std	55.740230	25.272741	10.023280	
min	3.694000	2.060000	1.002000	
25%	12.377500	5.215000	2.154500	
50%	24.245000	10.050000	3.480500	
75%	59.270000	21.800000	8.855250	
max	448.100000	220.000000	80.244000	

```
Westwick MDF (t-1)
                            Skelton MDF (t-1)
                                                Crakehill MDF (t-2)
               1448.000000
                                   1448.000000
                                                         1448.000000
count
mean
                 21.517077
                                     47.012696
                                                            19.532983
std
                 28.287685
                                     55.743271
                                                            25.273807
                  1.954000
                                      3.694000
                                                             2.060000
min
25%
                  5.609250
                                     12.377500
                                                             5.215000
50%
                 10.385000
                                     24.230000
                                                            10.000000
75%
                 26.724000
                                     59.270000
                                                            21.800000
                                    448.100000
                374.061000
                                                          220.000000
max
                                Westwick MDF (t-2)
                                                     Skelton MDF (t-2)
       Skip Bridge MDF (t-2)
                  1448.000000
                                       1448.000000
                                                            1448.000000
count
mean
                     7.605369
                                         21.513186
                                                              47.006191
std
                    10.023601
                                         28.289072
                                                              55.745308
min
                     1.002000
                                          1.954000
                                                               3.694000
25%
                     2.154500
                                          5.609250
                                                              12.377500
50%
                     3.480500
                                         10.354500
                                                              24.230000
75%
                     8.855250
                                         26.724000
                                                              59.270000
                    80.244000
                                        374.061000
                                                             448.100000
max
       Crakehill MDF (t-3)
                                 Malham Tarn DRT (t-1)
                                                         Snaizeholme DRT (t-1)
                1448.000000
                                            1448.000000
                                                                    1448.000000
count
                  19.531809
                                              14.010497
                                                                       9.652486
mean
std
                  25.274192
                                              25.065902
                                                                      20.953300
min
                   2.060000
                                               0.000000
                                                                       0.000000
25%
                   5.215000
                                               0.000000
                                                                       0.000000
50%
                  10.000000
                                               1.600000
                                                                       0.800000
75%
                  21.800000
                                              18.400000
                                                                      10.400000
max
                 220.000000
                                             252.000000
                                                                     268.800000
                                   East Cowton DRT (t-2)
                                                           Malham Tarn DRT (t-2)
       Arkengarthdale DRT (t-2)
                     1448.000000
                                              1448.000000
                                                                      1448.000000
count
                        5.783978
mean
                                                 5.295028
                                                                        14.007182
std
                       13.274272
                                                12.308373
                                                                        25.067332
                        0.000000
                                                 0.000000
                                                                         0.000000
min
25%
                        0.00000
                                                 0.000000
                                                                         0.000000
50%
                        0.800000
                                                 0.000000
                                                                         1.600000
75%
                        6.400000
                                                 5.300000
                                                                        18.400000
                      225.200000
                                               165.600000
                                                                       252.000000
max
       Snaizeholme DRT (t-2)
                                Arkengarthdale DRT (t-3)
                                                           East Cowton DRT (t-3)
count
                  1448.000000
                                              1448.000000
                                                                      1448.000000
                     9.649724
                                                 5.781768
                                                                         5.291713
mean
std
                    20.954309
                                                13.274969
                                                                        12.309152
                     0.000000
                                                 0.000000
                                                                         0.000000
min
25%
                     0.000000
                                                 0.000000
                                                                         0.000000
50%
                     0.800000
                                                 0.800000
                                                                         0.00000
```

```
75%
                         10.400000
                                                     6.400000
                                                                            5.300000
                        268.800000
                                                  225.200000
                                                                          165.600000
      max
             Malham Tarn DRT (t-3)
                                    Snaizeholme DRT (t-3)
                       1448.000000
                                              1448.000000
      count
                         14.007182
                                                  9.651934
     mean
      std
                         25.067332
                                                20.953544
     min
                          0.000000
                                                 0.000000
      25%
                          0.000000
                                                 0.000000
     50%
                          1.600000
                                                  0.800000
      75%
                         18.400000
                                                10.400000
     max
                        252.000000
                                               268.800000
      [8 rows x 25 columns]
     2.0.2 Moving Averages
[85]: moving_avg_df = pd.DataFrame()
      moving avg df["Date"] = clean df["Date"]
      moving_avg_df[flow_cols[-1]] = clean_df[flow_cols[-1]]
      moving avg df.head(10)
[85]:
               Date Skelton MDF (Cumecs)
      0 1993-01-01
                                    26.10
      1 1993-01-02
                                    24.86
      2 1993-01-03
                                    23.60
      3 1993-01-04
                                    23.47
      4 1993-01-05
                                    60.70
      5 1993-01-06
                                    98.01
      6 1993-01-07
                                    56.99
      7 1993-01-08
                                    56.66
      8 1993-01-09
                                    78.10
      9 1993-01-10
                                   125.70
[86]: # Creating moving averages of between 3 and 7 days for each numerical column
      for i in range(3, 8):
          for col in flow cols:
              col_name = col.replace("(Cumecs)", f"(MA{i})")
              moving_avg_df[col_name] = clean_df[col].rolling(i).mean()
      for i in range(3, 8):
          for col in rain cols:
              col_name = col.replace("(mm)", f"(MA{i})")
              moving avg df[col name] = clean df[col].rolling(i).mean()
      moving_avg_df.head(10)
```

```
[86]:
                       Skelton MDF (Cumecs)
                                               Crakehill MDF (MA3)
                Date
      0
         1993-01-01
                                       26.10
                                                                NaN
         1993-01-02
                                       24.86
                                                                NaN
      1
      2
         1993-01-03
                                       23.60
                                                           9.936667
      3
         1993-01-04
                                       23.47
                                                           9.606667
         1993-01-05
                                       60.70
      4
                                                          15.056667
      5
         1993-01-06
                                       98.01
                                                          22.603333
      6
         1993-01-07
                                       56.99
                                                          25.900000
      7
         1993-01-08
                                       56.66
                                                          24.466667
      8
         1993-01-09
                                       78.10
                                                          25.600000
         1993-01-10
                                      125.70
      9
                                                          36.166667
         Skip Bridge MDF (MA3)
                                   Westwick MDF (MA3)
                                                         Skelton MDF (MA3)
      0
                             NaN
                                                   NaN
                                                                        NaN
      1
                             NaN
                                                   NaN
                                                                        NaN
      2
                        4.252000
                                              8.656667
                                                                  24.853333
      3
                        4.242000
                                              8.201333
                                                                  23.976667
      4
                        6.816333
                                             24.895333
                                                                  35.923333
      5
                        8.854000
                                             33.681667
                                                                  60.726667
      6
                        9.817667
                                             38.461000
                                                                 71.900000
      7
                        8.252333
                                             28.755333
                                                                 70.553333
      8
                        7.557667
                                             37.367667
                                                                  63.916667
      9
                        9.565000
                                             61.263667
                                                                  86.820000
         Crakehill MDF (MA4)
                                Skip Bridge MDF (MA4)
                                                          Westwick MDF (MA4)
      0
                           NaN
                                                    NaN
                                                                          NaN
      1
                           NaN
                                                    NaN
                                                                          NaN
      2
                           NaN
                                                    NaN
                                                                          NaN
      3
                                                4.27975
                        9.8050
                                                                      8.47375
      4
                       13.7800
                                                6.17200
                                                                     20.82700
      5
                       19.3175
                                                7.67150
                                                                     27.27550
      6
                       21.7775
                                                8.45400
                                                                     30.82700
      7
                       24.9250
                                                9.17975
                                                                     36.24250
      8
                       27.2250
                                                8.22750
                                                                     36.62975
      9
                       31.9500
                                                8.98725
                                                                     51.51350
         Skelton MDF (MA4)
                                  Malham Tarn DRT (MA5)
                                                           Snaizeholme DRT (MA5)
      0
                         NaN
                                                     NaN
                                                                               NaN
      1
                         NaN
                                                     NaN
                                                                               NaN
      2
                         NaN
                                                     NaN
                                                                               NaN
      3
                    24.5075
                                                     NaN
                                                                               NaN
      4
                    33.1575
                                                    7.20
                                                                             35.36
      5
                    51.4450
                                                    7.52
                                                                             34.72
      6
                                                                             41.92
                    59.7925
                                                   10.88
      7
                    68.0900
                                                   11.04
                                                                            42.40
      8
                    72.4400
                                                   21.92
                                                                            51.04
      9
                    79.3625
                                                   30.40
                                                                            56.16
```

```
Arkengarthdale DRT (MA6) East Cowton DRT (MA6) Malham Tarn DRT (MA6)
      0
                                NaN
                                                        NaN
                                                                                 NaN
                                NaN
                                                        NaN
                                                                                 NaN
      1
      2
                                NaN
                                                        NaN
                                                                                 NaN
      3
                                NaN
                                                        NaN
                                                                                 NaN
      4
                                NaN
                                                        NaN
                                                                                 NaN
      5
                          2.266667
                                                   5.066667
                                                                            6.266667
      6
                          3.200000
                                                   5.733333
                                                                            9.200000
      7
                          3.466667
                                                   5.733333
                                                                            9.333333
      8
                          5.866667
                                                   5.866667
                                                                           18.400000
      9
                          8.933333
                                                   2.133333
                                                                           30.933333
         Snaizeholme DRT (MA6)
                                 Arkengarthdale DRT (MA7)
                                                              East Cowton DRT (MA7)
      0
                            NaN
                                                        NaN
                                                                                 NaN
                                                        NaN
      1
                            NaN
                                                                                 NaN
      2
                                                                                 NaN
                            NaN
                                                        NaN
      3
                                                        NaN
                                                                                 NaN
                            NaN
      4
                            NaN
                                                        NaN
                                                                                 NaN
      5
                      29.600000
                                                        NaN
                                                                                 NaN
      6
                      34.933333
                                                   2.742857
                                                                            4.914286
      7
                      35.333333
                                                   2.971429
                                                                            4.914286
      8
                      52.800000
                                                   5.028571
                                                                            5.028571
      9
                      65.333333
                                                   8.000000
                                                                            5.371429
         Malham Tarn DRT (MA7)
                                  Snaizeholme DRT (MA7)
                            NaN
      0
      1
                            NaN
                                                     NaN
      2
                            NaN
                                                     NaN
      3
                            NaN
                                                     NaN
      4
                            NaN
                                                     NaN
      5
                            NaN
                                                     NaN
                       7.885714
                                               30.514286
      7
                       8.114286
                                               30.285714
      8
                      15.885714
                                               45.257143
                      26.628571
                                               64.800000
      [10 rows x 42 columns]
[87]: # Dropping rows with null values
      moving_avg_df[moving_avg_df.isna().any(axis=1)]
[87]:
               Date Skelton MDF (Cumecs)
                                             Crakehill MDF (MA3)
        1993-01-01
                                      26.10
                                                               NaN
      1 1993-01-02
                                      24.86
                                                               NaN
      2 1993-01-03
                                      23.60
                                                         9.936667
      3 1993-01-04
                                      23.47
                                                         9.606667
```

```
4 1993-01-05
                                60.70
                                                   15.056667
5 1993-01-06
                                98.01
                                                   22.603333
                            Westwick MDF (MA3)
                                                  Skelton MDF (MA3)
   Skip Bridge MDF (MA3)
0
                      NaN
                                            NaN
                                                                 NaN
1
                      NaN
                                            NaN
                                                                 NaN
                 4.252000
2
                                      8.656667
                                                          24.853333
3
                 4.242000
                                      8.201333
                                                          23.976667
4
                 6.816333
                                      24.895333
                                                          35.923333
5
                 8.854000
                                      33.681667
                                                          60.726667
   Crakehill MDF (MA4)
                          Skip Bridge MDF (MA4)
                                                   Westwick MDF (MA4)
0
                    NaN
                                             NaN
                                                                   NaN
1
                    NaN
                                             NaN
                                                                   NaN
2
                    NaN
                                             NaN
                                                                   NaN
                 9.8050
                                         4.27975
3
                                                              8.47375
4
                                         6.17200
                                                              20.82700
                13.7800
5
                19.3175
                                         7.67150
                                                              27.27550
   Skelton MDF (MA4)
                           Malham Tarn DRT (MA5)
                                                    Snaizeholme DRT (MA5)
0
                  {\tt NaN}
                                              NaN
                                                                       NaN
1
                  NaN
                                              NaN
                                                                       NaN
2
                  NaN
                                              NaN
                                                                       NaN
3
              24.5075
                                              NaN
                                                                       NaN
4
              33.1575
                                             7.20
                                                                     35.36
5
              51.4450
                                             7.52
                                                                     34.72
   Arkengarthdale DRT (MA6)
                              East Cowton DRT (MA6)
                                                        Malham Tarn DRT (MA6)
0
                          NaN
                                                   NaN
                                                                            NaN
1
                          NaN
                                                   NaN
                                                                            NaN
2
                          NaN
                                                   NaN
                                                                            NaN
3
                          NaN
                                                   NaN
                                                                            NaN
4
                          NaN
                                                   NaN
                                                                            NaN
5
                    2.266667
                                             5.066667
                                                                      6.266667
   Snaizeholme DRT (MA6) Arkengarthdale DRT (MA7)
                                                        East Cowton DRT (MA7)
0
                      NaN
                                                   NaN
                                                                            NaN
1
                      NaN
                                                   NaN
                                                                            NaN
2
                      NaN
                                                   NaN
                                                                            NaN
3
                      NaN
                                                   NaN
                                                                            NaN
4
                      NaN
                                                   NaN
                                                                            NaN
5
                     29.6
                                                   NaN
                                                                            NaN
   Malham Tarn DRT (MA7)
                            Snaizeholme DRT (MA7)
0
                      NaN
                                               NaN
                      NaN
                                               NaN
1
2
                      NaN
                                               NaN
```

3	NaN	NaN
4	NaN	NaN
5	NaN	NaN

[6 rows x 42 columns]

[88]: moving_avg_df.dropna(how="any", inplace=True)
moving_avg_df[moving_avg_df.isna().any(axis=1)]

[88]: Empty DataFrame

Columns: [Date, Skelton MDF (Cumecs), Crakehill MDF (MA3), Skip Bridge MDF (MA3), Westwick MDF (MA3), Skelton MDF (MA3), Crakehill MDF (MA4), Skip Bridge MDF (MA4), Westwick MDF (MA4), Skelton MDF (MA4), Crakehill MDF (MA5), Skip Bridge MDF (MA5), Westwick MDF (MA5), Skelton MDF (MA5), Crakehill MDF (MA6), Skip Bridge MDF (MA6), Westwick MDF (MA6), Skelton MDF (MA6), Crakehill MDF (MA7), Skip Bridge MDF (MA7), Westwick MDF (MA7), Skelton MDF (MA7), Arkengarthdale DRT (MA3), East Cowton DRT (MA3), Malham Tarn DRT (MA3), Snaizeholme DRT (MA3), Arkengarthdale DRT (MA4), East Cowton DRT (MA4), Malham Tarn DRT (MA4), Snaizeholme DRT (MA4), Arkengarthdale DRT (MA5), East Cowton DRT (MA5), Malham Tarn DRT (MA6), Snaizeholme DRT (MA6), Snaizeholme DRT (MA6), Arkengarthdale DRT (MA7), East Cowton DRT (MA7), Snaizeholme DRT (MA7), Snaizeholme DRT (MA7), Snaizeholme DRT (MA7), Snaizeholme DRT (MA7),

Index: []

[0 rows x 42 columns]

[89]: moving avg df.describe()

[09].	moving	_avg_dr.describe()			
[89]:		Skelton MDF (Cumecs)	Crakehill MDF (M	A3) Skip Bridge MDF	(MA3) \
	count	1445.000000	1445.000	000 1445.0	000000
	mean	46.995172	19.545	218 7.6	308666
	std	55.777355	23.160	818 9.3	371964
	min	3.694000	2.083	333 1.0	012667
	25%	12.370000	5.383	333 2.:	176333
	50%	24.240000	10.276	667 3.5	568667
	75%	59.050000	23.966	667 9.5	565000
	max	448.100000	176.666	667 67.	550333
		Westwick MDF (MA3)	Skelton MDF (MA3)	Crakehill MDF (MA4)	\
	count	1445.000000	1445.000000	1445.000000	
	mean	21.515503	47.028298	19.546846	
	std	25.103715	52.756141	22.399448	
	min	1.990333	3.733000	2.095000	
	25%	5.825667	12.820000	5.585000	
	50%	10.934333	24.773333	10.435000	
	75%	29.075333	62.006667	25.050000	

max	251.526667	361.066667	158.250000	
	Skip Bridge MDF (MA4)	Westwick MDF (MA4) Ske	elton MDF (MA4) \	
count	1445.000000	1445.000000	1445.000000	
mean	7.609420	21.521166	47.033714	
std	9.116826	24.211841	51.530965	
min	1.014750	2.003750	3.834250	
25%	2.179500	5.850000	13.050000	
50%	3.593250	11.279000	25.365000	
75%	9.582250	29.579000	63.012500	
max	65.921750	216.440250	337.300000	
	Crakehill MDF (MA5)	Malham Tarn DRT (MA5)	Snaizeholme DRT (M	A5) \
count	1445.000000	1445.000000	1445.000	000
mean	19.547596	14.027183	9.613	619
std	21.768351	15.169586	12.909	387
min	2.110000	0.00000	0.000	000
25%	5.696000	1.760000	0.800	000
50%	10.806000	9.760000	4.960	000
75%	25.380000	21.120000	13.280	000
max	157.960000	90.240000	105.040	000
	Arkengarthdale DRT (MA	6) East Cowton DRT (MA6	S) Malham Tarn DRT	(MA6) \
count	1445.0000	00 1445.00000	1.44500	0e+03
mean	5.7922	03 5.29282	26 1.40271	3e+01
std	7.3013	13 6.07879	1.44620	1e+01
min	0.0000	0.00000	00 8.65974	0e-15
25%	0.6666	67 0.93333	33 2.13333	3e+00
50%	3.4666	67 3.46666	1.03333	3e+01
75%	8.4000	7.26666	2.14000	0e+01
max	73.4000	00 40.40000	9.73333	3e+01
	Snaizeholme DRT (MA6)	Arkengarthdale DRT (MA7	') East Cowton DRT	(MA7) \
count	1445.000000	1.445000e+0	1445.0	00000
mean	9.621961	5.791162e+0	00 5.2	91626
std	12.375209	6.983505e+0	5.7	32045
min	0.000000	5.075305e-1	.6 0.0	00000
25%	1.200000	8.00000e-0	1.2	57143
50%	5.333333	3.771429e+0	3.6	57143
75%	13.333333	8.342857e+0	7.1	42857
max	87.800000	6.965714e+0	35.2	00000
	Malham Tarn DRT (MA7)	Snaizeholme DRT (MA7)		
count	1.445000e+03	1445.000000		
mean	1.402709e+01	9.628314		
std	1.387434e+01	11.911054		
min	5.773160e-15	0.000000		

```
50%
                      1.051429e+01
                                                 5.828571
      75%
                      2.102857e+01
                                                13.371429
                      1.040571e+02
                                                75.257143
     max
      [8 rows x 41 columns]
[90]: # Creating lagged moving averages
      lagged_ma_df = pd.DataFrame()
      lagged_ma_df["Date"] = moving_avg_df["Date"]
      lagged_ma_df[flow_cols[-1]] = moving_avg_df[flow_cols[-1]]
      lagged_ma_df.head(10)
[90]:
                Date Skelton MDF (Cumecs)
          1993-01-07
                                     56.99
      6
      7
         1993-01-08
                                     56.66
                                     78.10
      8
         1993-01-09
                                    125.70
      9
         1993-01-10
      10 1993-01-11
                                    195.90
      11 1993-01-12
                                    125.40
      12 1993-01-13
                                    161.50
      13 1993-01-14
                                    204.00
      14 1993-01-15
                                    200.60
      15 1993-01-16
                                    234.40
[91]: ## Lagging moving averages by 1 day
      ## lagging them by more than 1 day results in much weaker correlations
      mdf_cols = list(moving_avg_df.columns[2:22])
      drt_cols = list(moving_avg_df.columns[22:])
      for col in mdf_cols:
          col_name = col + f'' (t-1)''
          lagged_ma_df[col_name] = moving_avg_df[col].shift(1)
      for col in drt cols:
          col_name = col + f'' (t-1)''
          lagged_ma_df[col_name] = moving_avg_df[col].shift(1)
      lagged_ma_df.head(10)
「91]:
                Date Skelton MDF (Cumecs)
                                            Crakehill MDF (MA3) (t-1) \
      6
         1993-01-07
                                     56.99
                                                                  NaN
      7
         1993-01-08
                                     56.66
                                                            25.900000
      8
         1993-01-09
                                     78.10
                                                            24.466667
      9
          1993-01-10
                                    125.70
                                                            25.600000
      10 1993-01-11
                                    195.90
                                                            36.166667
      11 1993-01-12
                                    125.40
                                                            50.666667
```

25%

2.171429e+00

```
12 1993-01-13
                               161.50
                                                         49.500000
                               204.00
13 1993-01-14
                                                         53.933333
14 1993-01-15
                               200.60
                                                         55.133333
   1993-01-16
                                234.40
                                                         76.000000
    Skip Bridge MDF (MA3) (t-1) Westwick MDF (MA3) (t-1) \
6
                             NaN
7
                        9.817667
                                                   38.461000
8
                        8.252333
                                                   28.755333
9
                        7.557667
                                                  37.367667
                        9.565000
10
                                                   61.263667
11
                       15.663333
                                                  74.569000
12
                       19.850667
                                                   67.989333
13
                       27.605333
                                                  72.256667
14
                       28.570667
                                                  69.197333
15
                       32.919333
                                                  103.079000
    Skelton MDF (MA3) (t-1) Crakehill MDF (MA4) (t-1) \
6
                         NaN
                                                      NaN
7
                   71.900000
                                                  21.7775
8
                   70.553333
                                                  24.9250
9
                   63.916667
                                                  27.2250
10
                   86.820000
                                                  31.9500
11
                  133.233333
                                                  43.5000
12
                  149.000000
                                                  46.0000
13
                  160.933333
                                                  53.2000
14
                  163.633333
                                                  57.7250
15
                  188.700000
                                                  65.0000
    Skip Bridge MDF (MA4) (t-1) Westwick MDF (MA4) (t-1)
6
                             NaN
                                                         NaN
7
                                                    30.82700
                         8.45400
8
                         9.17975
                                                    36.24250
9
                         8.22750
                                                    36.62975
10
                         8.98725
                                                    51.51350
11
                        13.56400
                                                   63.32350
12
                        16.92625
                                                   66.05525
13
                        24.02300
                                                   77.68025
14
                        27.81825
                                                    69.27375
15
                        29.86825
                                                    87.43775
    Skelton MDF (MA4) (t-1) ... Malham Tarn DRT (MA5) (t-1)
6
                         NaN ...
                                                           NaN
                     59.7925 ...
7
                                                         10.88
8
                     68.0900 ...
                                                         11.04
                                                         21.92
9
                     72.4400 ...
                     79.3625 ...
                                                         30.40
10
```

```
32.48
11
                    114.0900
12
                    131.2750
                                                          29.12
                                                          45.36
13
                    152.1250
                    171.7000
                                                          35.92
14
15
                    172.8750
                                                          35.12
    Snaizeholme DRT (MA5) (t-1)
                                   Arkengarthdale DRT (MA6) (t-1)
6
                              NaN
                                                                NaN
7
                                                           3.200000
                            41.92
8
                            42.40
                                                           3.466667
9
                            51.04
                                                           5.866667
10
                            56.16
                                                           8.933333
11
                            61.60
                                                           8.800000
                            59.20
12
                                                          10.000000
13
                            82.32
                                                          15.600000
14
                            63.92
                                                          16.266667
15
                            50.96
                                                          19.866667
                                   Malham Tarn DRT (MA6) (t-1)
    East Cowton DRT (MA6) (t-1)
6
                              NaN
                                                             NaN
7
                        5.733333
                                                        9.200000
8
                        5.733333
                                                        9.333333
9
                        5.866667
                                                       18.400000
10
                        2.133333
                                                       30.933333
11
                        3.866667
                                                       27.333333
12
                        4.533333
                                                       27.200000
13
                        5.333333
                                                       38.066667
14
                        5.600000
                                                       39.133333
15
                        7.466667
                                                       41.933333
    Snaizeholme DRT (MA6) (t-1)
                                   Arkengarthdale DRT (MA7) (t-1)
6
                              NaN
                                                                NaN
7
                       34.933333
                                                           2.742857
8
                                                           2.971429
                       35.333333
9
                       52.800000
                                                           5.028571
10
                       65.333333
                                                           8.000000
11
                       51.466667
                                                           9.142857
12
                       55.333333
                                                           8.571429
                                                          14.171429
13
                       69.000000
14
                       70.733333
                                                          14.171429
15
                       65.266667
                                                          19.085714
                                   Malham Tarn DRT (MA7) (t-1) \
    East Cowton DRT (MA7) (t-1)
6
                              NaN
                                                             NaN
7
                        4.914286
                                                        7.885714
                        4.914286
8
                                                        8.114286
9
                        5.028571
                                                       15.885714
```

```
4.114286
                                                           28.228571
      11
      12
                              3.885714
                                                           23.542857
      13
                              5.142857
                                                           35.142857
      14
                              4.800000
                                                           33.771429
      15
                                                           43.828571
                              6.514286
          Snaizeholme DRT (MA7) (t-1)
      6
                                   NaN
      7
                             30.514286
      8
                             30.285714
      9
                             45.257143
      10
                             64.800000
      11
                            60.000000
      12
                            47.542857
      13
                            64.285714
      14
                            60.971429
      15
                            70.914286
      [10 rows x 42 columns]
[92]: # Dropping rows with null values
      lagged_ma_df[lagged_ma_df.isna().any(axis=1)]
[92]:
               Date Skelton MDF (Cumecs) Crakehill MDF (MA3) (t-1)
      6 1993-01-07
                                     56.99
                                                                   NaN
         Skip Bridge MDF (MA3) (t-1) Westwick MDF (MA3) (t-1)
      6
                                 NaN
                                                             NaN
         Skelton MDF (MA3) (t-1) Crakehill MDF (MA4) (t-1) \
      6
                              NaN
         Skip Bridge MDF (MA4) (t-1) Westwick MDF (MA4) (t-1) \
                                  NaN
                                                             NaN
         Skelton MDF (MA4) (t-1) ... Malham Tarn DRT (MA5) (t-1) \
      6
                              NaN ...
                                                               NaN
                                       Arkengarthdale DRT (MA6) (t-1)
         Snaizeholme DRT (MA5) (t-1)
      6
         East Cowton DRT (MA6) (t-1)
                                       Malham Tarn DRT (MA6) (t-1) \
      6
                                  NaN
                                                                NaN
         Snaizeholme DRT (MA6) (t-1)
                                       Arkengarthdale DRT (MA7) (t-1)
      6
                                 NaN
                                                                   NaN
```

26.628571

10

```
East Cowton DRT (MA7) (t-1) Malham Tarn DRT (MA7) (t-1) \
6
                           NaN
                                                         NaN
  Snaizeholme DRT (MA7) (t-1)
6
                           NaN
[1 rows x 42 columns]
```

```
[93]: lagged_ma_df.dropna(how="any", inplace=True)
      lagged_ma_df[lagged_ma_df.isna().any(axis=1)]
```

[93]: Empty DataFrame

Columns: [Date, Skelton MDF (Cumecs), Crakehill MDF (MA3) (t-1), Skip Bridge MDF (MA3) (t-1), Westwick MDF (MA3) (t-1), Skelton MDF (MA3) (t-1), Crakehill MDF (MA4) (t-1), Skip Bridge MDF (MA4) (t-1), Westwick MDF (MA4) (t-1), Skelton MDF (MA4) (t-1), Crakehill MDF (MA5) (t-1), Skip Bridge MDF (MA5) (t-1), Westwick MDF (MA5) (t-1), Skelton MDF (MA5) (t-1), Crakehill MDF (MA6) (t-1), Skip Bridge MDF (MA6) (t-1), Westwick MDF (MA6) (t-1), Skelton MDF (MA6) (t-1), Crakehill MDF (MA7) (t-1), Skip Bridge MDF (MA7) (t-1), Westwick MDF (MA7) (t-1), Skelton MDF (MA7) (t-1), Arkengarthdale DRT (MA3) (t-1), East Cowton DRT (MA3) (t-1), Malham Tarn DRT (MA3) (t-1), Snaizeholme DRT (MA3) (t-1), Arkengarthdale DRT (MA4) (t-1), East Cowton DRT (MA4) (t-1), Malham Tarn DRT (MA4) (t-1), Snaizeholme DRT (MA4) (t-1), Arkengarthdale DRT (MA5) (t-1), East Cowton DRT (MA5) (t-1), Malham Tarn DRT (MA5) (t-1), Snaizeholme DRT (MA5) (t-1), Arkengarthdale DRT (MA6) (t-1), East Cowton DRT (MA6) (t-1), Malham Tarn DRT (MA6) (t-1), Snaizeholme DRT (MA6) (t-1), Arkengarthdale DRT (MA7) (t-1), East Cowton DRT (MA7) (t-1), Malham Tarn DRT (MA7) (t-1), Snaizeholme DRT (MA7) (t-1)]

Index: []

count

[0 rows x 42 columns]

[94]: lagged_ma_df.describe()

[94]:		Skelton MDF (Cumecs)	Crakehill MDF (MA3) (t-1)	\
	count	1444.000000	1444.000000	
	mean	46.988251	19.548435	
	std	55.796058	23.168519	
	min	3.694000	2.083333	
	25%	12.352500	5.377500	
	50%	24.230000	10.263333	
	75%	59.100000	24.016667	
	max	448.100000	176.666667	

1444.000000

Skip Bridge MDF (MA3) (t-1) Westwick MDF (MA3) (t-1) \

```
7.609933
                                                     21.521265
mean
                           9.375087
                                                     25.111456
std
min
                           1.012667
                                                      1.990333
25%
                           2.174250
                                                      5.824167
50%
                           3.567667
                                                     10.922667
75%
                           9.570917
                                                     29.109167
                                                    251.526667
                          67.550333
max
       Skelton MDF (MA3) (t-1) Crakehill MDF (MA4) (t-1)
                    1444.000000
                                                1444.000000
count
                      47.037087
                                                  19.550722
mean
std
                      52.773360
                                                  22.406724
min
                       3.733000
                                                   2.095000
25%
                      12.803333
                                                   5.574375
50%
                      24.756667
                                                  10.430000
75%
                      62.124167
                                                  25.050000
                     361.066667
                                                 158.250000
max
       Skip Bridge MDF (MA4) (t-1) Westwick MDF (MA4) (t-1) \
                        1444.000000
                                                   1444.000000
count
                                                     21.527241
mean
                           7.610739
                                                     24.219128
std
                           9.119847
min
                           1.014750
                                                      2.003750
25%
                           2.178812
                                                      5.848125
50%
                           3.592375
                                                     11.259750
75%
                           9.585000
                                                     29.589500
                                                    216.440250
max
                          65.921750
       Skelton MDF (MA4) (t-1)
                                 Crakehill MDF (MA5) (t-1)
                    1444.000000
                                                1444.000000
count
                      47.043488
                                                  19.551895
mean
                                                  21.775279
std
                      51.547477
min
                       3.834250
                                                   2.110000
25%
                      13.049875
                                                   5.694000
50%
                      25.341250
                                                  10.803000
75%
                      63.085000
                                                  25.390000
                     337.300000
                                                 157.960000
max
       Malham Tarn DRT (MA5) (t-1) Snaizeholme DRT (MA5) (t-1)
                        1444.000000
                                                      1444.000000
count
                          14.033352
mean
                                                          9.618393
std
                          15.173028
                                                         12.912583
                           0.000000
min
                                                          0.000000
25%
                           1.760000
                                                          0.800000
50%
                           9.760000
                                                         4.960000
75%
                          21.140000
                                                        13.300000
                          90.240000
max
                                                       105.040000
```

```
min
                                    0.000000
                                                                   0.00000
      25%
                                    0.666667
                                                                   0.933333
      50%
                                    3.466667
                                                                   3.466667
      75%
                                    8.400000
                                                                   7.266667
                                   73.400000
      max
                                                                  40.400000
             Malham Tarn DRT (MA6) (t-1)
                                           Snaizeholme DRT (MA6) (t-1)
      count
                             1.444000e+03
                                                            1444.000000
                             1.403389e+01
                                                               9.627054
      mean
                             1.446474e+01
                                                              12.377981
      std
      min
                             8.659740e-15
                                                               0.000000
      25%
                             2.133333e+00
                                                               1.200000
      50%
                             1.033333e+01
                                                               5.333333
      75%
                             2.140000e+01
                                                              13.333333
                             9.733333e+01
                                                              87.800000
      max
             Arkengarthdale DRT (MA7) (t-1) East Cowton DRT (MA7) (t-1)
                                1.444000e+03
                                                               1444.000000
      count
      mean
                                5.791848e+00
                                                                   5.290305
      std
                                6.985875e+00
                                                                   5.733811
      min
                                5.075305e-16
                                                                   0.000000
                                8.000000e-01
                                                                   1.257143
      25%
      50%
                                3.771429e+00
                                                                   3.657143
      75%
                                8.342857e+00
                                                                   7.100000
                                6.965714e+01
                                                                  35.200000
      max
             Malham Tarn DRT (MA7) (t-1)
                                           Snaizeholme DRT (MA7) (t-1)
                             1.444000e+03
                                                            1444.000000
      count
      mean
                             1.403419e+01
                                                               9.633478
      std
                             1.387652e+01
                                                              11.913562
      min
                             5.773160e-15
                                                               0.00000
      25%
                             2.171429e+00
                                                               1.371429
      50%
                             1.051429e+01
                                                               5.828571
      75%
                             2.104286e+01
                                                              13.371429
                             1.040571e+02
      max
                                                              75.257143
      [8 rows x 41 columns]
[95]: # Creating weighted moving averages
      weighted_ma_df = pd.DataFrame()
      weighted_ma_df["Date"] = clean_df["Date"]
      weighted_ma_df[flow_cols[-1]] = clean_df[flow_cols[-1]]
```

Arkengarthdale DRT (MA6) (t-1) East Cowton DRT (MA6) (t-1) \

1444.000000

5.291043

6.080526

1444.000000

5.792336

7.303841

count

mean

std

```
weighted_ma_df.head(10)
[95]:
               Date
                     Skelton MDF (Cumecs)
         1993-01-01
                                    26.10
      1 1993-01-02
                                    24.86
      2 1993-01-03
                                    23.60
      3 1993-01-04
                                    23.47
      4 1993-01-05
                                    60.70
      5 1993-01-06
                                    98.01
      6 1993-01-07
                                    56.99
      7 1993-01-08
                                    56.66
      8 1993-01-09
                                    78.10
      9 1993-01-10
                                   125.70
[96]: | ## Creating weighted moving averages of between 3 and 7 days for each numerical
      ⇔column
      for i in range(3, 8):
          for col in flow_cols:
              col_name = col.replace("(Cumecs)", f"(WMA{i})")
              weighted_ma_df[col_name] = clean_df[col].ewm(span=i).mean()
      for i in range(3, 8):
          for col in rain_cols:
              col_name = col.replace("(mm)", f"(WMA{i})")
              weighted_ma_df[col_name] = clean_df[col].ewm(span=i).mean()
      weighted_ma_df.head(10)
[96]:
               Date
                     Skelton MDF (Cumecs)
                                           Crakehill MDF (WMA3)
        1993-01-01
                                    26.10
                                                       10.400000
      1 1993-01-02
                                                       10.100000
                                    24.86
      2 1993-01-03
                                    23.60
                                                        9.734286
      3 1993-01-04
                                    23.47
                                                        9.561333
      4 1993-01-05
                                    60.70
                                                       18.200645
      5 1993-01-06
                                    98.01
                                                       25.260635
      6 1993-01-07
                                    56.99
                                                       22.256850
      7 1993-01-08
                                    56.66
                                                       22.127922
                                                       28.827045
      8 1993-01-09
                                    78.10
      9 1993-01-10
                                   125.70
                                                       39.924360
         Skip Bridge MDF (WMA3)
                                 Westwick MDF (WMA3)
                                                      Skelton MDF (WMA3)
      0
                       4.393000
                                            9.291000
                                                                26.100000
                       4.290333
                                            8.845000
                                                                25.273333
      1
      2
                       4.195286
                                            8.394714
                                                                24.317143
      3
                       4.284733
                                            8.144200
                                                                23.865333
      4
                       8.247194
                                           34.239581
                                                                42.876774
      5
                       9.257889
                                           34.329190
                                                                70.880952
```

```
6
                  8.248055
                                       28.248591
                                                             63.880787
7
                  7.755102
                                       28.920420
                                                             60.256235
8
                  7.954440
                                       44.617368
                                                             69.195577
9
                 10.617821
                                       69.308296
                                                             97.475406
   Crakehill MDF (WMA4)
                          Skip Bridge MDF (WMA4)
                                                    Westwick MDF (WMA4)
0
               10.400000
                                         4.393000
                                                                9.291000
1
               10.118750
                                         4.296750
                                                                8.872875
2
                9.782653
                                         4.208612
                                                                8.456612
3
                                                                8.212305
                9.611397
                                         4.279562
4
               16.849688
                                         7.611640
                                                               30.111895
5
               23.248349
                                         8.713177
                                                               31.917793
6
               21.623524
                                         8.112697
                                                               27.944653
7
               21.776687
                                         7.768232
                                                               28.612815
8
               27.321895
                                         7.923706
                                                               41.397731
9
               36.850755
                                        10.077648
                                                               62.546920
   Skelton MDF (WMA4)
                           Malham Tarn DRT (WMA5)
                                                     Snaizeholme DRT (WMA5)
                                                                    4.000000
0
            26.100000
                                          0.000000
            25.325000
                                           0.480000
                                                                    1.600000
1
2
            24.444898
                                           0.631579
                                                                    0.842105
3
            23.996875
                                          0.701538
                                                                   26.080000
4
            39.915996
                                         13.330806
                                                                   58.756398
5
            64.290830
                                          9.044211
                                                                   37.578346
6
            61.286393
                                         12.073434
                                                                   37.019524
7
            59.404222
                                          8.440539
                                                                   25.011134
            66.958665
8
                                         24.443295
                                                                   52.317730
9
            90.598138
                                         41.932146
                                                                   80.975455
                                East Cowton DRT (WMA6)
                                                         Malham Tarn DRT (WMA6)
   Arkengarthdale DRT (WMA6)
0
                     0.000000
                                               0.00000
                                                                         0.000000
1
                     0.000000
                                               0.00000
                                                                         0.466667
2
                     0.000000
                                               0.000000
                                                                         0.616514
3
                     0.927027
                                               9.579279
                                                                         0.687387
4
                     4.532554
                                                                        12.238795
                                               8.182663
5
                     3.039206
                                               5.486709
                                                                        8.733616
6
                     3.847544
                                                                        11.532371
                                               5.017416
7
                     3.158713
                                               3.479670
                                                                        8.488282
8
                     6.533868
                                               2.675109
                                                                        22.513302
9
                    10.755867
                                               2.593692
                                                                        38.342455
   Snaizeholme DRT (WMA6)
                             Arkengarthdale DRT (WMA7)
                                                         East Cowton DRT (WMA7)
0
                  4.000000
                                               0.00000
                                                                         0.00000
1
                  1.666667
                                               0.000000
                                                                         0.000000
2
                  0.917431
                                               0.00000
                                                                         0.00000
3
                 24.356757
                                               0.877714
                                                                         9.069714
4
                 54.836310
                                               4.261204
                                                                        7.932394
```

6	36	3.706846		3.72540	07	5.0814	1')
7		3.700040 3.192430		3.13494		3.6697	
8).794060		6.17983		2.8940	
9							
9	75	5.543086		10.05298	84	2.7631	12
Ma	lham Tarn DRT	' (WMA7)	Snaizeholme DF	RT (WMA7)			
0	0	0.00000		4.000000			
1	0	.457143		1.714286			
2	0	.605405		0.972973			
3	0	.676571	2	23.145143			
4	11	.468374	Ę	52.008195			
5	8	3.467122	3	36.434333			
6	11	.102064	3	36.309023			
7	8	3.462270	2	26.888668			
8	21	.095246	4	47.947713			
9	35	6.640530	7	71.486327			
	ows x 42 colu ted_ma_df.des						
	GI I. MDE	. (0	0 1 1 · 1 · 1 · MT	NE (17440)	al. D.I MDE	(17040)	`
:					Skip Bridge MDF		\
count	14	151.000000	145	51.000000	1451.	.000000	\
count mean	14	151.000000 46.977784	145	51.000000 19.519175	1451. 7.	.000000	\
count mean std	14	46.977784 55.691669	145	51.000000 19.519175 22.509756	1451. 7. 9.	.000000 .600024 .131015	\
count mean std min	14	46.977784 55.691669 3.694000	145	51.000000 19.519175 22.509756 2.106613	1451. 7. 9. 1.	.000000 .600024 .131015 .013019	\
count mean std min 25%	14	46.977784 55.691669 3.694000 12.385000	145	51.000000 19.519175 22.509756 2.106613 5.537138	1451. 7. 9. 1. 2.	.000000 .600024 .131015 .013019 .189022	\
count mean std min 25% 50%	14	46.977784 55.691669 3.694000 12.385000 24.250000	145	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988	1451. 7. 9. 1. 2.	.000000 .600024 .131015 .013019 .189022 .595440	\
count mean std min 25% 50% 75%	14	46.977784 55.691669 3.694000 12.385000 24.250000	145	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073	1451. 7. 9. 1. 2. 3. 9.	000000 600024 131015 013019 189022 595440 343599	\
count mean std min 25% 50%	14	46.977784 55.691669 3.694000 12.385000 24.250000	145	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988	1451. 7. 9. 1. 2. 3. 9.	.000000 .600024 .131015 .013019 .189022 .595440	\
count mean std min 25% 50% 75%	14	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000	145	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253	1451. 7. 9. 1. 2. 3. 9.	000000 600024 131015 013019 189022 595440 343599 767533	\
count mean std min 25% 50% 75%	14 Westwick MD	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000	145	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra	1451. 7. 9. 1. 2. 3. 9. 66.	000000 600024 131015 013019 189022 595440 343599 767533	\
count mean std min 25% 50% 75% max	14 Westwick MD 145	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000	145 2 17 Skelton MDF (1451.0	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra	1451. 7. 9. 1. 2. 3. 9. 66.	000000 600024 131015 013019 189022 595440 343599 767533	
count mean std min 25% 50% 75% max	14 Westwick MD 145 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000	145 2 17 Skelton MDF (1451.0 46.9	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4	000000 600024 131015 013019 189022 595440 343599 767533	
count mean std min 25% 50% 75% max count mean std min	4 Westwick MD 145 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 0F (WMA3) 51.000000 21.492349 24.494882 1.988822	145 2 17 Skelton MDF 1451.0 46.9 51.8	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463	000000 600024 131015 013019 189022 595440 343599 767533 1) \	
count mean std min 25% 50% 75% max count mean std min 25%	4 Westwick MD 145 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 0F (WMA3) 51.000000 21.492349 24.494882	145 2 17 Skelton MDF (1451.0 46.9 51.5 3.7 12.9	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857	000000 600024 131015 013019 189022 595440 343599 767533 1) \	
count mean std min 25% 50% 75% max count mean std min 25% 50%	14 Westwick MD 145 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 0F (WMA3) 51.000000 21.492349 24.494882 1.988822	145 2 17 Skelton MDF (1451.0 46.9 51.5 3.7 12.9	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463	000000 600024 131015 013019 189022 595440 343599 767533 4) \	
count mean std min 25% 50% 75% max count mean std min 25%	14 Westwick MD 145 2 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 0F (WMA3) 51.000000 21.492349 24.494882 1.988822 5.931549	145 2 17 Skelton MDF (46.9 51.9 3.7 12.9 25.2	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471	000000 600024 131015 013019 189022 595440 343599 767533 1) \ 00 67 74 33 10	
count mean std min 25% 50% 75% max count mean std min 25% 50%	14 Westwick MD 145 2 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 0F (WMA3) 51.00000 21.492349 24.494882 1.988822 5.931549	148 2 17 2 17 2 1451.0 46.9 51.8 3.7 12.9 25.2 63.8	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008 273333	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471 10.76470	000000 600024 131015 013019 189022 595440 343599 767533 1) \ 00 67 74 33 10 07	
count mean std min 25% 50% 75% max count mean std min 25% 50% 75%	14 Westwick MD 145 2 2	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 21.492349 24.494882 1.988822 5.931549 1.193894 29.361253 33.847215	148 3 3 17 Skelton MDF (46.9 51.8 3.7 12.9 25.2 63.8 358.3	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008 273333 598434 363081	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471 10.76470 24.93590 163.37457	000000 600024 131015 013019 189022 595440 343599 767533 4) \ 00 67 74 33 10 07 07	
count mean std min 25% 50% 75% max count mean std min 25% 50% 75%	4 Westwick MD 145 2 2 Skip Bridge	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 21.492349 24.494882 1.988822 5.931549 1.193894 29.361253 33.847215	148 2 17 2 17 2 1451.0 46.9 51.8 3.7 12.9 25.2 63.8 358.3	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008 273333 598434 363081	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471 10.76470 24.93590 163.37457	000000 600024 131015 013019 189022 595440 343599 767533 1) \ 00 67 74 83 10 07 77 74	
count mean std min 25% 50% 75% max count mean std min 25% 50% 75% max	4 Westwick MD 145 2 2 Skip Bridge	151.000000 46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 148.100000 148.100000 1492349 24.494882 1.988822 5.931549 1.193894 29.361253 33.847215 MDF (WMA 1451.0000	148 2 17 2 17 2 1451.0 46.9 51.8 3.7 12.9 25.2 63.8 358.3 4) Westwick M	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008 273333 598434 363081 MDF (WMA4) 451.000000	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471 10.76470 24.93590 163.37457 Skelton MDF (WM	000000 600024 131015 013019 189022 595440 343599 767533 1) \ 00 67 74 33 10 07 77 74 104) \ 10000	
count mean std min 25% 50% 75% max count mean std min 25% 50% 75% max count	4 Westwick MD 145 2 2 Skip Bridge	46.977784 55.691669 3.694000 12.385000 24.250000 59.150000 48.100000 21.492349 24.494882 1.988822 5.931549 1.193894 29.361253 33.847215	148 2 17 Skelton MDF (1451.0 46.9 51.8 3.7 12.9 25.2 63.8 358.3 4) Westwick MOO 14	51.000000 19.519175 22.509756 2.106613 5.537138 10.408988 24.015073 71.548253 (WMA3) Cra 000000 971894 546413 784612 991008 273333 598434 363081	1451. 7. 9. 1. 2. 3. 9. 66. akehill MDF (WMA4 1451.00000 19.51876 21.70857 2.12463 5.66471 10.76470 24.93590 163.37457 Skelton MDF (WM 1451.0000 46.971	000000 600024 131015 013019 189022 595440 343599 767533 4) \ 00 67 74 33 10 07 07 74 MA4) \ 0000 1182	

5.519929

5

```
25%
                      2.200730
                                            6.034924
                                                                13.232278
50%
                      3.623453
                                           11.656633
                                                                25.870124
75%
                      9.732283
                                           29.933482
                                                                62.757663
                     63.330198
                                          252.563531
                                                               342.371380
max
       Crakehill MDF (WMA5)
                                 Malham Tarn DRT (WMA5)
                 1451.000000
                                             1451.000000
count
mean
                   19.518829
                                               13.984398
                   21.070805
std
                                               14.834316
                    2.143048
                                                0.000000
min
25%
                    5.781697
                                                2.396532
50%
                   11.025246
                                                9.522856
75%
                   24.765063
                                               21.230186
                  155.556128
                                              105.652838
max
       Snaizeholme DRT (WMA5)
                                Arkengarthdale DRT (WMA6)
                   1451.000000
                                               1451.000000
count
                                                   5.775847
mean
                      9.651831
std
                     12.682914
                                                   7.117200
                      0.000023
                                                   0.000000
min
25%
                      1.361718
                                                   1.034738
50%
                      5.152346
                                                  3.629764
75%
                     12.726148
                                                  8.114486
                     97.166216
max
                                                 83.577971
       East Cowton DRT (WMA6)
                                Malham Tarn DRT (WMA6)
                                                          Snaizeholme DRT (WMA6)
                   1451.000000
                                            1451.000000
                                                                      1451.000000
count
                      5.286105
                                              13.985534
                                                                         9.659651
mean
                                              14.046123
std
                      5.928408
                                                                        12.084998
min
                      0.00000
                                               0.000000
                                                                         0.000130
25%
                      1.297775
                                               2.864697
                                                                         1.573018
50%
                      3.479670
                                              10.051803
                                                                         5.627342
75%
                      7.154646
                                              21.351626
                                                                       12.777683
max
                     51.966182
                                             100.117414
                                                                       86.247750
       Arkengarthdale DRT (WMA7)
                                   East Cowton DRT (WMA7)
                      1451.000000
                                               1451.000000
count
                         5.775058
                                                   5.284842
mean
std
                         6.759876
                                                   5.554247
                         0.000000
                                                   0.000000
min
25%
                         1.227319
                                                   1.504496
50%
                         3.795612
                                                  3.669731
75%
                         8.044823
                                                  7.163909
                        77.825716
                                                  45.744930
max
       Malham Tarn DRT (WMA7)
                                Snaizeholme DRT (WMA7)
                   1451.000000
                                            1451.000000
count
```

```
11.612662
      std
                          13.408911
     min
                          0.000000
                                                   0.000424
      25%
                          3.248877
                                                   1.729078
      50%
                         10.562586
                                                  5.856426
      75%
                          21.049487
                                                  12.844838
     max
                          95.347821
                                                  80.502521
      [8 rows x 41 columns]
[98]: # Creating lagged weighted moving averages
      lagged_wma_df = pd.DataFrame()
      lagged_wma_df["Date"] = weighted_ma_df["Date"]
      lagged_wma_df[flow_cols[-1]] = weighted_ma_df[flow_cols[-1]]
      lagged_wma_df.head(10)
[98]:
               Date Skelton MDF (Cumecs)
      0 1993-01-01
                                    26.10
      1 1993-01-02
                                    24.86
      2 1993-01-03
                                    23.60
      3 1993-01-04
                                    23.47
      4 1993-01-05
                                    60.70
      5 1993-01-06
                                    98.01
      6 1993-01-07
                                    56.99
      7 1993-01-08
                                    56.66
     8 1993-01-09
                                    78.10
      9 1993-01-10
                                   125.70
[99]: # Lagging weighted moving averages
      w_mdf_cols = list(weighted_ma_df.columns[2:22])
      w_drt_cols = list(weighted_ma_df.columns[22:])
      for col in w_mdf_cols:
          col name = col + f'' (t-1)''
          lagged_wma_df[col_name] = weighted_ma_df[col].shift(1)
      for col in w_drt_cols:
          col name = col + f'' (t-1)''
          lagged_wma_df[col_name] = weighted_ma_df[col].shift(1)
      lagged_wma_df.head(10)
[99]:
               Date Skelton MDF (Cumecs) Crakehill MDF (WMA3) (t-1) \
      0 1993-01-01
                                    26.10
                                                                  NaN
      1 1993-01-02
                                    24.86
                                                            10.400000
      2 1993-01-03
                                    23.60
                                                            10.100000
      3 1993-01-04
                                    23.47
                                                             9.734286
```

13.986942

mean

```
4 1993-01-05
                               60.70
                                                         9.561333
5 1993-01-06
                               98.01
                                                        18.200645
6 1993-01-07
                               56.99
                                                        25.260635
7 1993-01-08
                               56.66
                                                        22.256850
 1993-01-09
                               78.10
                                                        22.127922
9 1993-01-10
                              125.70
                                                        28.827045
   Skip Bridge MDF (WMA3) (t-1) Westwick MDF (WMA3) (t-1) \
0
                             NaN
                                                         NaN
1
                        4.393000
                                                    9.291000
2
                        4.290333
                                                    8.845000
3
                        4.195286
                                                    8.394714
4
                        4.284733
                                                    8.144200
5
                        8.247194
                                                   34.239581
6
                                                   34.329190
                        9.257889
7
                        8.248055
                                                   28.248591
8
                        7.755102
                                                   28.920420
9
                        7.954440
                                                   44.617368
   Skelton MDF (WMA3) (t-1) Crakehill MDF (WMA4) (t-1) \
0
                         NaN
                                                      NaN
1
                  26.100000
                                                10.400000
2
                  25.273333
                                                10.118750
3
                  24.317143
                                                 9.782653
4
                  23.865333
                                                 9.611397
5
                  42.876774
                                                16.849688
6
                  70.880952
                                                23.248349
7
                  63.880787
                                                21.623524
8
                  60.256235
                                                21.776687
9
                  69.195577
                                                27.321895
   Skip Bridge MDF (WMA4) (t-1) Westwick MDF (WMA4) (t-1) \
0
                                                         NaN
                        4.393000
                                                    9.291000
1
2
                        4.296750
                                                    8.872875
3
                        4.208612
                                                    8.456612
4
                        4.279562
                                                    8.212305
5
                        7.611640
                                                   30.111895
6
                        8.713177
                                                   31.917793
7
                        8.112697
                                                   27.944653
8
                        7.768232
                                                   28.612815
9
                        7.923706
                                                   41.397731
   Skelton MDF (WMA4) (t-1) ... Malham Tarn DRT (WMA5) (t-1) \
0
                         {\tt NaN}
                                                           NaN
                  26.100000
                                                      0.000000
1
2
                  25.325000
                                                      0.480000
```

```
3
                   24.444898
                                                        0.631579
4
                   23.996875
                                                        0.701538
5
                   39.915996
                                                       13.330806
6
                   64.290830
                                                        9.044211
7
                   61.286393
                                                       12.073434
8
                   59.404222
                                                        8.440539
9
                   66.958665
                                                       24.443295
   Snaizeholme DRT (WMA5) (t-1)
                                   Arkengarthdale DRT (WMA6) (t-1)
0
1
                        4.000000
                                                            0.000000
2
                        1.600000
                                                            0.000000
3
                        0.842105
                                                            0.000000
4
                       26.080000
                                                            0.927027
5
                       58.756398
                                                            4.532554
                                                            3.039206
6
                       37.578346
7
                       37.019524
                                                            3.847544
8
                       25.011134
                                                            3.158713
9
                       52.317730
                                                            6.533868
   East Cowton DRT (WMA6) (t-1)
                                   Malham Tarn DRT (WMA6) (t-1) \
0
                              NaN
                                                              NaN
1
                        0.000000
                                                         0.000000
2
                        0.000000
                                                         0.466667
3
                                                         0.616514
                        0.00000
4
                        9.579279
                                                         0.687387
5
                        8.182663
                                                        12.238795
6
                        5.486709
                                                         8.733616
7
                        5.017416
                                                        11.532371
8
                        3.479670
                                                         8.488282
9
                        2.675109
                                                        22.513302
   Snaizeholme DRT (WMA6) (t-1)
                                   Arkengarthdale DRT (WMA7) (t-1)
0
                              NaN
                                                                 NaN
1
                        4.000000
                                                            0.000000
2
                        1.666667
                                                            0.000000
3
                                                            0.000000
                        0.917431
4
                       24.356757
                                                            0.877714
5
                       54.836310
                                                            4.261204
6
                       37.032886
                                                            2.965251
7
                       36.706846
                                                            3.725407
8
                       26.192430
                                                            3.134942
9
                       49.794060
                                                            6.179831
   East Cowton DRT (WMA7) (t-1)
                                   Malham Tarn DRT (WMA7) (t-1)
0
                              NaN
                                                              NaN
1
                        0.000000
                                                         0.000000
```

```
3
                               0.000000
                                                              0.605405
       4
                               9.069714
                                                              0.676571
       5
                               7.932394
                                                             11.468374
       6
                               5.519929
                                                              8.467122
       7
                               5.081412
                                                             11.102064
       8
                               3.669731
                                                              8.462270
       9
                               2.894057
                                                             21.095246
          Snaizeholme DRT (WMA7) (t-1)
       0
                                    NaN
       1
                               4.000000
       2
                               1.714286
       3
                               0.972973
       4
                              23.145143
       5
                              52.008195
       6
                              36.434333
       7
                              36.309023
                              26.888668
                              47.947713
       [10 rows x 42 columns]
[100]: lagged_wma_df[lagged_wma_df.isna().any(1)]
[100]:
                Date Skelton MDF (Cumecs) Crakehill MDF (WMA3) (t-1) \
       0 1993-01-01
                                       26.1
                                                                      NaN
          Skip Bridge MDF (WMA3) (t-1) Westwick MDF (WMA3) (t-1) \
       0
          Skelton MDF (WMA3) (t-1) Crakehill MDF (WMA4) (t-1) \
       0
                                NaN
                                                             NaN
          Skip Bridge MDF (WMA4) (t-1)
                                         Westwick MDF (WMA4) (t-1)
       0
                                    NaN
                                                                NaN
          Skelton MDF (WMA4) (t-1) ... Malham Tarn DRT (WMA5) (t-1) \
       0
                                {\tt NaN}
                                                                  {\tt NaN}
          Snaizeholme DRT (WMA5) (t-1)
                                        Arkengarthdale DRT (WMA6) (t-1) \
       0
                                    NaN
                                                                       NaN
          East Cowton DRT (WMA6) (t-1) Malham Tarn DRT (WMA6) (t-1) \
       0
                                    NaN
                                                                    {\tt NaN}
          Snaizeholme DRT (WMA6) (t-1) Arkengarthdale DRT (WMA7) (t-1) \
```

0.457143

2

O NaN NaN

East Cowton DRT (WMA7) (t-1) Malham Tarn DRT (WMA7) (t-1) $\$ NaN NaN

Snaizeholme DRT (WMA7) (t-1) 0 NaN

[1 rows x 42 columns]

[101]: lagged_wma_df.dropna(how="any", inplace=True) lagged_wma_df[lagged_wma_df.isna().any(1)]

[101]: Empty DataFrame

Columns: [Date, Skelton MDF (Cumecs), Crakehill MDF (WMA3) (t-1), Skip Bridge MDF (WMA3) (t-1), Westwick MDF (WMA3) (t-1), Skelton MDF (WMA3) (t-1), Crakehill MDF (WMA4) (t-1), Skip Bridge MDF (WMA4) (t-1), Westwick MDF (WMA4) (t-1), Skelton MDF (WMA4) (t-1), Crakehill MDF (WMA5) (t-1), Skip Bridge MDF (WMA5) (t-1), Westwick MDF (WMA5) (t-1), Skelton MDF (WMA5) (t-1), Crakehill MDF (WMA6) (t-1), Skip Bridge MDF (WMA6) (t-1), Westwick MDF (WMA6) (t-1), Skelton MDF (WMA6) (t-1), Crakehill MDF (WMA7) (t-1), Skip Bridge MDF (WMA7) (t-1), Westwick MDF (WMA7) (t-1), Skelton MDF (WMA7) (t-1), Arkengarthdale DRT (WMA3) (t-1), East Cowton DRT (WMA3) (t-1), Malham Tarn DRT (WMA3) (t-1), Snaizeholme DRT (WMA3) (t-1), Arkengarthdale DRT (WMA4) (t-1), East Cowton DRT (WMA4) (t-1), Malham Tarn DRT (WMA4) (t-1), Snaizeholme DRT (WMA4) (t-1), Arkengarthdale DRT (WMA5) (t-1), East Cowton DRT (WMA5) (t-1), Malham Tarn DRT (WMA5) (t-1), Snaizeholme DRT (WMA5) (t-1), Arkengarthdale DRT (WMA6) (t-1), East Cowton DRT (WMA6) (t-1), Malham Tarn DRT (WMA6) (t-1), Snaizeholme DRT (WMA6) (t-1), Arkengarthdale DRT (WMA7) (t-1), East Cowton DRT (WMA7) (t-1), Malham Tarn DRT (WMA7) (t-1), Snaizeholme DRT (WMA7) (t-1)]

Index: []

[0 rows x 42 columns]

[102]: lagged_wma_df.describe()

[102]:	Skelton MDF (Cumecs)	Crakehill MDF (WMA3) (t-1)
count	1450.000000	1450.000000
mean	46.992182	19.522053
std	55.708181	22.517255
min	3.694000	2.106613
25%	12.382500	5.534470
50%	24.245000	10.407141
75%	59.200000	24.051890
max	448.100000	171.548253

Skip Bridge MDF (WMA3) (t-1) Westwick MDF (WMA3) (t-1) \

\

count	1450.000000	1450.000000
mean	7.601166	21.497952
std	9.134062	24.502403
min	1.013019	1.988822
25%	2.188817	5.928907
50%	3.595122	11.170101
75%	9.386454	29.367607
max	66.767533	283.847215
	331.3.333	
	Skelton MDF (WMA3) (t-1) Cra	akehill MDF (WMA4) (t-1) \
count	1450.000000	1450.000000
mean	46.979458	19.521839
std	51.563392	21.715748
min	3.784612	2.124633
25%	12.988892	5.652475
50%	25.272767	10.740245
		24.975226
75%	63.638607	
max	358.363081	163.374574
	Clair Decider MDE (IMAA) (+ 1)	United ADE (UMAA) (+ 1)
+	-	Westwick MDF (WMA4) (t-1) \
count	1450.000000	1450.000000
mean	7.600470	21.498375
std	8.857104	23.560109
min	1.015611	2.003615
25%	2.199878	6.030254
50%	3.621673	11.629449
75%	9.753887	29.937759
max	63.330198	252.563531
	Skelton MDF (WMA4) (t-1) Cra	
count	1450.000000	1450.000000
mean	46.978713	19.521840
std	50.220109	21.077762
min	3.813018	2.143048
25%	13.230015	5.778349
50%	25.859974	11.015578
75%	62.787376	24.787001
max	342.371380	155.556128
	Malham Tarn DRT (WMA5) (t-1)	Snaizeholme DRT (WMA5) (t-1) \
count	1450.000000	1450.000000
mean	13.990728	9.656912
std	14.837473	12.685812
min	0.000000	0.000023
25%	2.392643	1.360390
50%	9.528469	5.157073
75%	21.253441	12.729215
70	21.200111	12., 20210

max	105.652838	97.166216

count mean std min 25% 50% 75% max	Arkengarthdale DRT (WMA6) (t- 1450.0000 5.7754 7.1196 0.0000 1.0339 3.6286 8.1188 83.5779	26 5.284441 37 5.930115 00 0.000000 39 1.293475 86 3.478350 00 7.146410
count mean std min 25% 50% 75% max	Malham Tarn DRT (WMA6) (t-1) 1450.000000 13.991815 14.048930 0.000000 2.855575 10.064458 21.354523 100.117414	Snaizeholme DRT (WMA6) (t-1) \
count mean std min 25% 50% 75% max	Arkengarthdale DRT (WMA7) (t- 1450.0000 5.7746 6.7621 0.0000 1.2271 3.7924 8.0497 77.8257	54 5.283198 91 5.555810 00 0.000000 86 1.504081 45 3.664996 64 7.160675
count mean std min 25% 50% 75% max	Malham Tarn DRT (WMA7) (t-1) 1450.000000 13.993078 13.411499 0.0000000 3.244706 10.593781 21.058371 95.347821	Snaizeholme DRT (WMA7) (t-1) 1450.000000 9.673086 11.615246 0.000424 1.728840 5.863176 12.848060 80.502521

[8 rows x 41 columns]

2.0.3 Exporting Datasets

[103]:	lagged	_df.describe()			
[103]:		Skelton MDF (Cumecs)	Crakehill MDF (t-	1) Skip Bridge MDF	(t-1) \
	count	1448.000000	1448.0000	00 1448.0	000000
	mean	47.023622	19.5370	23 7.0	606707
	std	55.740230	25.2727	41 10.0	023280
	min	3.694000	2.0600	00 1.0	002000
	25%	12.377500	5.2150	00 2.	154500
	50%	24.245000	10.0500	00 3.4	180500
	75%	59.270000	21.8000	00 8.8	355250
	max	448.100000	220.0000	00 80.3	244000
		Westwick MDF (t-1) S	kelton MDF (t-1)	Crakehill MDF (t-2)	\
	count	1448.000000	1448.000000	1448.000000	
	mean	21.517077	47.012696	19.532983	
	std	28.287685	55.743271	25.273807	
	min	1.954000	3.694000	2.060000	
	25%	5.609250	12.377500	5.215000	
	50%	10.385000	24.230000	10.000000	
	75%	26.724000	59.270000	21.800000	
	max	374.061000	448.100000	220.000000	
		Skip Bridge MDF (t-2)	Westwick MDF (t-	2) Skelton MDF (t-:	2) \
	count	1448.000000	1448.0000	00 1448.0000	00
	mean	7.605369	21.5131	86 47.00619	91
	std	10.023601	28.2890	72 55.74530	08
	min	1.002000			00
	25%	2.154500			
	50%	3.480500			
	75%	8.855250			
	max	80.244000	374.0610	00 448.1000	00
		Crakehill MDF (t-3)	Malham Tarn DRT	(t-1) Snaizeholme	DRT (t-1) \
	count	1448.000000	1448.	000000 14	148.000000
	mean	19.531809	14.	010497	9.652486
	std	25.274192	25.	065902	20.953300
	min	2.060000	0.	000000	0.000000
	25%	5.215000	0.	000000	0.000000
	50%	10.000000	1.	600000	0.800000
	75%	21.800000	18.	400000	10.400000
	max	220.000000	252.	000000	268.800000
		Arkengarthdale DRT (t	-2) East Cowton D	RT (t-2) Malham Ta:	rn DRT (t-2) \
	count	1448.000		8.000000	1448.000000
	mean	5.783		5.295028	14.007182

	std	13.27	4272	12.3	08373		25.06	7332	
	min	0.00000			00000			0000	
	25%	0.00000			00000			0000	
	50%	0.80			00000			0000	
	75%	6.400			00000		18.40		
	max	225.200		165.6			252.00		
		Snaizeholme DRT (t-2)) Arkengarthd	ale DRT	(t-3) Ea	st Cowton	DRT (t-3)	\
	count	1448.00000	_	1448.0			448.00		·
	mean	9.64972			81768			1713	
	std	20.954309			74969		12.30		
	min	0.00000			00000			0000	
	25%	0.00000			00000			0000	
	50%	0.80000			00000			0000	
	75%	10.40000			00000			0000	
	max	268.800000		225.2			165.60		
	max	200.00000		220.2	00000		100.00	.0000	
		Malham Tarn DRT (t-3)) Snaizeholme	DRT (t-	3)				
	count	1448.00000		448.0000					
	mean	14.007182		9.6519	34				
	std	25.06733		20.9535					
	min	0.00000		0.0000					
	25%	0.00000		0.0000					
	50%	1.600000		0.8000					
	75%	18.40000		10.4000					
	max	252.00000		268.8000					
	[8 row	s x 25 columns]							
١.		_avg_df.describe()							
	moving	_avg_dr.describe()							
:		Skelton MDF (Cumecs)	Crakehill MD	F (MA3)	Skip Bri	dge MDF ((MA3)	\	
	count	1445.000000	1445	.000000	_	1445.00			
	mean	46.995172	19	.545218		7.60	8666		
	std	55.777355	23	.160818		9.37	1964		
	min	3.694000	2	.083333		1.01	2667		
	25%	12.370000	5	.383333		2.17	76333		
	50%	24.240000		.276667			88667		
	75%	59.050000	23	.966667			5000		
	max	448.100000		.666667		67.55			
		Westwick MDF (MA3)	Skelton MDF (M	A3) Cra	kehill MD	F (MA4)	\		
	count	1445.000000	1445.000	000	1445	.000000			
	mean	21.515503	47.028	298	19	.546846			
	std	25.103715	52.756	141	22	.399448			
	min	1.990333	3.733	000	2	.095000			
	~ = 0/				_				

[104]

[104]

25%

12.820000

5.585000

50%	10.934333	24.773333	10.435000	
75%	29.075333	62.006667	25.050000	
max	251.526667	361.066667	158.250000	
	Skip Bridge MDF (MA4)	Westwick MDF (MA4) S	Skelton MDF (MA4) \	
count	1445.000000	1445.000000	1445.000000	
mean	7.609420	21.521166	47.033714	
std	9.116826	24.211841	51.530965	
min	1.014750	2.003750	3.834250	
25%	2.179500	5.850000	13.050000	
50%	3.593250	11.279000	25.365000	
75%	9.582250	29.579000	63.012500	
max	65.921750	216.440250	337.300000	
	Crakehill MDF (MA5)			\
count	1445.000000			
mean	19.547596			
std	21.768351	15.16958		
min	2.110000	0.00000		
25%	5.696000	1.76000		
50%	10.806000			
75%	25.380000	21.12000		
max	157.960000	90.24000	105.040000	
	Arkengarthdale DRT (MA	6) East Cowton DRT (M	MA6) Malham Tarn DRT (MA6) \
count	Arkengarthdale DRT (MA			
count	1445.0000	00 1445.000	1.445000e+0	3
mean	1445.0000 5.7922	00 1445.000 03 5.292	1.445000e+0 2826 1.402713e+0	3 1
mean std	1445.0000 5.7922 7.3013	00 1445.000 03 5.292 13 6.078	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0	3 1 1
mean std min	1445.0000 5.7922 7.3013 0.0000	00 1445.000 03 5.292 13 6.078 00 0.000	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0 0000 8.659740e-1	3 1 1 5
mean std min 25%	1445.0000 5.7922 7.3013 0.0000 0.6666	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0 0000 8.659740e-1 3333 2.133333e+0	3 1 1 5 0
mean std min 25% 50%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466	1.445000e+0 1.445000e+0 1.402713e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.43333 1.43333e+0 1.033333e+0	3 1 1 5 0
mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266	1.445000e+0 1.445000e+0 1.402713e+0 1.446201e+0 1.446201e+0 1.4333 1.43333e+0 1.3333e+0 1.033333e+0 1.033333e+0 1.033339e+0	3 1 1 5 0 1
mean std min 25% 50%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266	1.445000e+0 1.445000e+0 1.402713e+0 1.446201e+0 1.446201e+0 1.4333 1.43333e+0 1.3333e+0 1.033333e+0 1.033333e+0 1.033339e+0	3 1 1 5 0 1
mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0 3333 2.133333e+0 3667 1.033333e+0 3667 2.140000e+0 3000 9.733333e+0	3 1 1 5 0 1 1
mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400	1.445000e+0 1.445000e+0 1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 0.000 1.446201e+0 0.000 1.446201e+0 1.43333 1.43333e+0 1.033333e+0 0.667 1.033333e+0 0.667 2.140000e+0 0.000 9.733333e+0 0.000 0.000 0.0000 0.0000 0.0000 0.00000 0.00000 0.000000	3 1 1 5 0 1 1 1
mean std min 25% 50% 75% max	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6)	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0 3333 2.133333e+0 3667 1.033333e+0 3667 2.140000e+0 3000 9.733333e+0 447) East Cowton DRT (MA7 34+03 1445.00000	3 1 1 5 0 1 1 1 1
mean std min 25% 50% 75% max	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (Markengarthdale DRT (Markengarthdale DRT)	1.445000e+0 2826 1.402713e+0 2797 1.446201e+0 2833 2.133333e+0 2.6667 1.033333e+0 2.140000e+0 2.140000e+0 2.140000e+0 3.657 2.140000e+0 3.733333e+0 3.657 3.	3 1 1 5 0 1 1 1 1 0 0
mean std min 25% 50% 75% max count mean	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M.1.4450006) 5.791162e	1.445000e+0 1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.43333 1.133333e+0 1.033333e+0 1.033336e+0 1.033333e+0 1.033336e+0 1.033333e+0 1.033336e+0 1.033333e+0 1.033336e+0 1.033336e+0 1.033333e+0 1.033336e+0 1.03336e+0 1.03366e+0 1.03366e+0 1.03366e+0 1.03666e+0 1.03666e+0 1.03666e+0 1.03666e+0 1.03666e+0 1.03666	3 1 1 5 0 1 1 1 0 6 5
mean std min 25% 50% 75% max count mean std	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M 1.445000e 5.791162e 6.983505e	1.445000e+0 2826 1.402713e+0 3797 1.446201e+0 3333 2.133333e+0 3667 1.033333e+0 3667 2.140000e+0 3.733333e+0 3.73204 3.73204 3.73204	3 1 1 5 0 1 1 1 1 0 6 5 0
mean std min 25% 50% 75% max count mean std min	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.0000000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M.1.445000e 5.791162e 6.983505e 5.075305e	1.445000e+0 2826 1.402713e+0 2797 1.446201e+0 2833 2.133333e+0 2.133333e+0 2.140000e+0 2.140000e+0 2.140000e+0 2.140000e+0 2.1400000 3.657 2.140000e+0 3.667 2.140000e+0 3.733333e+0 3.667 2.1400000e+0 3.733333e+0 3.667 2.1400000e+0 3.733333e+0 3.667 2.14000000 3.733333e+0 3.667 3.29162 3.667 3.29	3 1 1 5 0 1 1 1 1 0 6 5 0 0 3
mean std min 25% 50% 75% max count mean std min 25%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.000000 1.200000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M.1.445000e) 5.791162e 6.983505e 5.075305e 8.000000e	1.445000e+0 2826 1.402713e+0 2877 1.446201e+0 2800 8.659740e-1 28333 2.133333e+0 28667 1.033333e+0 28667 2.140000e+0 2800 9.733333e+0 28140 1445.00000 28140 5.29162 28160 5.73204 28160 9.700000 28161 1.25714 28160 3.65714	3 1 1 5 0 1 1 1 0 6 5 0 3 3
mean std min 25% 50% 75% max count mean std min 25% 50%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.000000 1.200000 5.3333333	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (Markengarthdale DRT) 1.445000e 5.791162e 6.983505e 5.075305e 8.000000e 3.771429e	1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.43333 1.133333e+0 1.033333e+0 1.03333e+0 1.03336e+0 1.03333e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.0336e+0 1.0336e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+	3 1 1 5 0 1 1 1 0 6 5 0 3 3 7
mean std min 25% 50% 75% max count mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.000000 1.200000 5.333333 13.333333 87.800000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (Markengarthdale DRT) 1.4450006 5.7911626 6.9835056 5.0753056 8.0000006 3.7714296 8.3428576 6.9657146	1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.43333 1.13333e+0 1.033333e+0 1.033339e+0 1.03339e+0 1.03339e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+0 1.03399e+	3 1 1 5 0 1 1 1 0 6 5 0 3 3 7
mean std min 25% 50% 75% max count mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.000000 1.200000 5.333333 13.333333 87.800000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (M 1.445000e 5.791162e 6.983505e 5.075305e 8.000000e 3.771429e 8.342857e 6.965714e Snaizeholme DRT (MA7)	1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 1.446201e+0 1.446201e+0 1.43333 1.133333e+0 1.033333e+0 1.03333e+0 1.03336e+0 1.03333e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.03336e+0 1.0336e+0 1.0336e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0 1.0366e+0	3 1 1 5 0 1 1 1 0 6 5 0 3 3 7
mean std min 25% 50% 75% max count mean std min 25% 50% 75%	1445.0000 5.7922 7.3013 0.0000 0.6666 3.4666 8.4000 73.4000 Snaizeholme DRT (MA6) 1445.000000 9.621961 12.375209 0.000000 1.200000 5.333333 13.333333 87.800000	00 1445.000 03 5.292 13 6.078 00 0.000 67 0.933 67 3.466 00 7.266 00 40.400 Arkengarthdale DRT (Markengarthdale DRT) 1.4450006 5.7911626 6.9835056 5.0753056 8.0000006 3.7714296 8.3428576 6.9657146	1.445000e+0 1.445000e+0 1.445000e+0 1.446201e+0 1.446201e+0 1.43333 1.133333e+0 1.033333e+0 1.03333e+0 1.03333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033339e+0 1.033333e+0 1.033339e+0 1.033333e+0 1.033339e+0 1.033339e+0 1.033333e+0 1.033339e+0 1.033339e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033333e+0 1.033339e+0 1.033333e+0 1.033339e+0 1.03339e+0 1.03339e+0 1.03339e+0 1.03339e+0 1.03339e+0 1.033	3 1 1 5 0 1 1 1 0 6 5 0 3 3 7

std	1.387434e+01	11.911054
min	5.773160e-15	0.000000
25%	2.171429e+00	1.371429
50%	1.051429e+01	5.828571
75%	2.102857e+01	13.371429
max	1.040571e+02	75.257143

[8 rows x 41 columns]

[105]: lagged_ma_df.describe()

[105]:		Skelton MDF (Cumecs)	Crakehill MDF (MA	13) (t-1) \	
	count	1444.000000		14.000000	
	mean	46.988251	1	19.548435	
	std	55.796058	2	23.168519	
	min	3.694000		2.083333	
	25%	12.352500		5.377500	
	50%	24.230000	1	10.263333	
	75%	59.100000		24.016667	
	max	448.100000		76.666667	
		Skip Bridge MDF (MA3)	(t-1) Westwick M	MDF (MA3) (t-1)	\
	count	1444.0	00000	1444.000000	
	mean	7.6	09933	21.521265	
	std	9.3	75087	25.111456	
	min	1.0	12667	1.990333	
	25%	2.1	74250	5.824167	
	50%	3.5	67667	10.922667	
	75%	9.5	70917	29.109167	
	max	67.5	50333	251.526667	
		Skelton MDF (MA3) (t-1			
	count	1444.00000		1444.000000	
	mean	47.03708		19.550722	
	std	52.77336		22.406724	
	min	3.73300		2.095000	
	25%	12.80333		5.574375	
	50%	24.75666		10.430000	
	75%	62.12416	7	25.050000	
	max	361.06666	7	158.250000	
		Skip Bridge MDF (MA4)			\
	count	1444.0		1444.000000	
	mean		10739	21.527241	
	std		19847	24.219128	
	min		14750	2.003750	
	25%	2.1	78812	5.848125	

```
50%
                           3.592375
                                                     11.259750
75%
                           9.585000
                                                     29.589500
max
                          65.921750
                                                    216.440250
       Skelton MDF (MA4) (t-1)
                                 Crakehill MDF (MA5) (t-1)
                    1444.000000
                                                1444.000000
count
                      47.043488
                                                  19.551895
mean
std
                      51.547477
                                                  21.775279
min
                       3.834250
                                                   2.110000
25%
                                                   5.694000
                      13.049875
50%
                      25.341250
                                                  10.803000
75%
                      63.085000
                                                  25.390000
max
                     337.300000
                                                 157.960000
       Malham Tarn DRT (MA5) (t-1)
                                     Snaizeholme DRT (MA5) (t-1)
                        1444.000000
                                                       1444.000000
count
                          14.033352
mean
                                                          9.618393
std
                          15.173028
                                                         12.912583
min
                           0.00000
                                                          0.00000
25%
                           1.760000
                                                          0.800000
50%
                           9.760000
                                                          4.960000
                          21.140000
75%
                                                        13.300000
                          90.240000
                                                        105.040000
max
       Arkengarthdale DRT (MA6) (t-1)
                                         East Cowton DRT (MA6) (t-1)
count
                           1444.000000
                                                          1444.000000
mean
                              5.792336
                                                             5.291043
                              7.303841
                                                             6.080526
std
min
                              0.000000
                                                             0.000000
25%
                              0.666667
                                                             0.933333
50%
                              3.466667
                                                             3.466667
75%
                              8.400000
                                                             7.266667
                             73.400000
max
                                                            40.400000
       Malham Tarn DRT (MA6) (t-1)
                                      Snaizeholme DRT (MA6) (t-1)
count
                       1.444000e+03
                                                       1444.000000
                       1.403389e+01
                                                          9.627054
mean
std
                       1.446474e+01
                                                         12.377981
min
                       8.659740e-15
                                                          0.000000
25%
                       2.133333e+00
                                                          1.200000
50%
                       1.033333e+01
                                                          5.333333
75%
                       2.140000e+01
                                                         13.333333
                       9.733333e+01
                                                        87.800000
max
       Arkengarthdale DRT (MA7) (t-1) East Cowton DRT (MA7) (t-1)
                          1.444000e+03
                                                          1444.000000
count
                          5.791848e+00
mean
                                                             5.290305
```

std	6.985875e+	00 5.733811
min	5.075305e-	
25%	8.000000e-	
50%	3.771429e+	
75%	8.342857e+	
	6.965714e+	
max	0.903/146+	55.200000
	Malham Tarn DRT (MA7) (t-1)	Snaizeholme DRT (MA7) (t-1)
count	1.444000e+03	1444.000000
mean	1.403419e+01	9.633478
std	1.387652e+01	11.913562
min	5.773160e-15	0.000000
25%	2.171429e+00	1.371429
50%	1.051429e+01	5.828571
75%	2.104286e+01	13.371429
max	1.040571e+02	75.257143
[8 row	s x 41 columns]	
[106]: lagged	d_wma_df.describe()	
[106]:	Skelton MDF (Cumecs) Crakeh	
count	1450.000000	1450.000000
mean	46.992182	19.522053
std	55.708181	22.517255
min	3.694000	2.106613
25%	12.382500	5.534470
50%	24.245000	10.407141
75%	59.200000	24.051890
max	448.100000	171.548253
	Skip Bridge MDF (WMA3) (t-1)	Westwick MDF (WMA3) (t-1) \
count	1450.000000	
mean	7.601166	21.497952
std	9.134062	
min	1.013019	
25%	2.188817	
50%	3.595122	
75%	9.386454	
max	66.767533	
		akehill MDF (WMA4) (t-1) \
count	1450.000000	1450.000000
mean	46.979458	19.521839
std	51.563392	21.715748
min	3.784612	2.124633

12.988892

25%

```
50%
                       25.272767
                                                    10.740245
75%
                       63.638607
                                                    24.975226
max
                      358.363081
                                                   163.374574
       Skip Bridge MDF (WMA4) (t-1) Westwick MDF (WMA4) (t-1)
                         1450.000000
                                                      1450.000000
count
                            7.600470
                                                        21.498375
mean
std
                            8.857104
                                                        23.560109
min
                            1.015611
                                                         2.003615
25%
                            2.199878
                                                         6.030254
50%
                            3.621673
                                                        11.629449
75%
                            9.753887
                                                       29.937759
max
                           63.330198
                                                      252.563531
       Skelton MDF (WMA4) (t-1)
                                  Crakehill MDF (WMA5) (t-1)
                     1450.000000
count
                                                  1450.000000
                       46.978713
                                                    19.521840
mean
std
                       50.220109
                                                    21.077762
min
                        3.813018
                                                      2.143048
25%
                       13.230015
                                                     5.778349
50%
                       25.859974
                                                    11.015578
75%
                       62.787376
                                                    24.787001
                      342.371380
                                                   155.556128
max
       Malham Tarn DRT (WMA5) (t-1)
                                       Snaizeholme DRT (WMA5) (t-1)
count
                         1450.000000
                                                         1450.000000
                           13.990728
                                                            9.656912
mean
                           14.837473
                                                           12.685812
std
min
                            0.000000
                                                            0.000023
25%
                            2.392643
                                                            1.360390
50%
                            9.528469
                                                            5.157073
75%
                           21.253441
                                                           12.729215
                          105.652838
max
                                                           97.166216
       Arkengarthdale DRT (WMA6) (t-1)
                                          East Cowton DRT (WMA6) (t-1)
count
                            1450.000000
                                                            1450.000000
                               5.775426
                                                               5.284441
mean
std
                                                               5.930115
                               7.119637
min
                               0.000000
                                                               0.000000
25%
                               1.033939
                                                               1.293475
50%
                               3.628686
                                                               3.478350
75%
                               8.118800
                                                               7.146410
                              83.577971
                                                              51.966182
max
       Malham Tarn DRT (WMA6) (t-1)
                                      Snaizeholme DRT (WMA6) (t-1)
                         1450.000000
                                                         1450.000000
count
                           13.991815
mean
                                                            9.664587
```

```
std
                           14.048930
                                                           12.087704
min
                            0.000000
                                                            0.000130
25%
                            2.855575
                                                            1.571982
50%
                           10.064458
                                                            5.628753
75%
                           21.354523
                                                           12.786220
                          100.117414
                                                           86.247750
max
       Arkengarthdale DRT (WMA7) (t-1) East Cowton DRT (WMA7) (t-1)
                            1450.000000
                                                            1450.000000
count
mean
                               5.774654
                                                               5.283198
std
                               6.762191
                                                               5.555810
min
                               0.000000
                                                               0.00000
25%
                               1.227186
                                                               1.504081
50%
                               3.792445
                                                               3.664996
75%
                               8.049764
                                                               7.160675
                              77.825716
                                                              45.744930
max
       Malham Tarn DRT (WMA7) (t-1)
                                       Snaizeholme DRT (WMA7) (t-1)
                         1450.000000
                                                         1450.000000
count
mean
                           13.993078
                                                            9.673086
std
                           13.411499
                                                           11.615246
min
                            0.000000
                                                            0.000424
25%
                            3.244706
                                                            1.728840
50%
                           10.593781
                                                            5.863176
75%
                           21.058371
                                                           12.848060
max
                           95.347821
                                                           80.502521
[8 rows x 41 columns]
```

```
[107]: # Exporting datasets with lags and moving averages
       lagged_df.to_excel('River-Data-Lagged.xlsx')
      moving_avg_df.to_excel('River-Data-MA.xlsx')
       lagged_ma_df.to_excel('River-Data-MA-Lagged.xlsx')
       weighted_ma_df.to_excel('River-Data-WMA.xlsx')
       lagged wma df.to excel('River-Data-WMA-Lagged.xlsx')
```