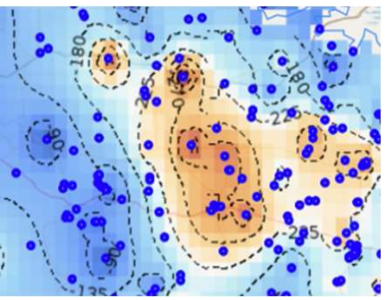
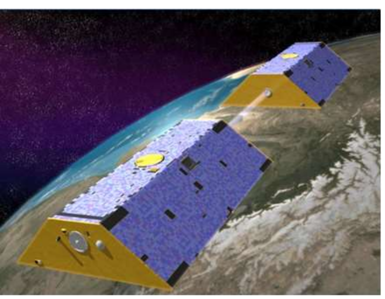
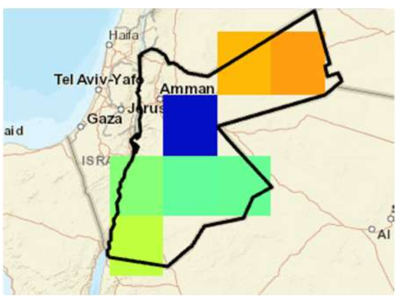
The Water Table Fluctuation Method for Recharge Estimation

Use of the Gravity Recovery and Climate Experiment (GRACE) mission to monitor groundwater storage change: National workshop for Jordan and State of Palestine

Amman Jordan, February 25-26







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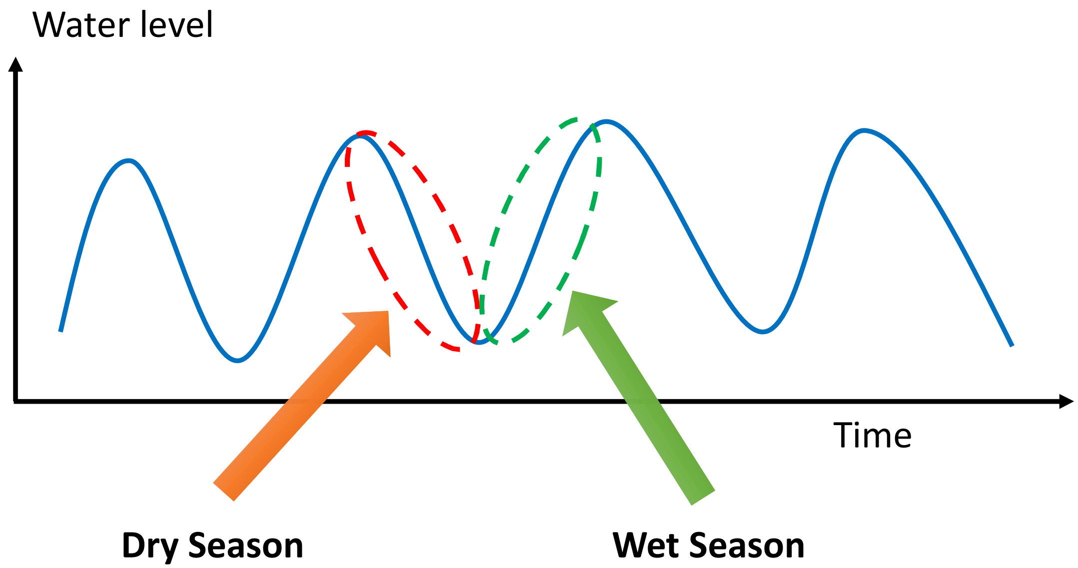
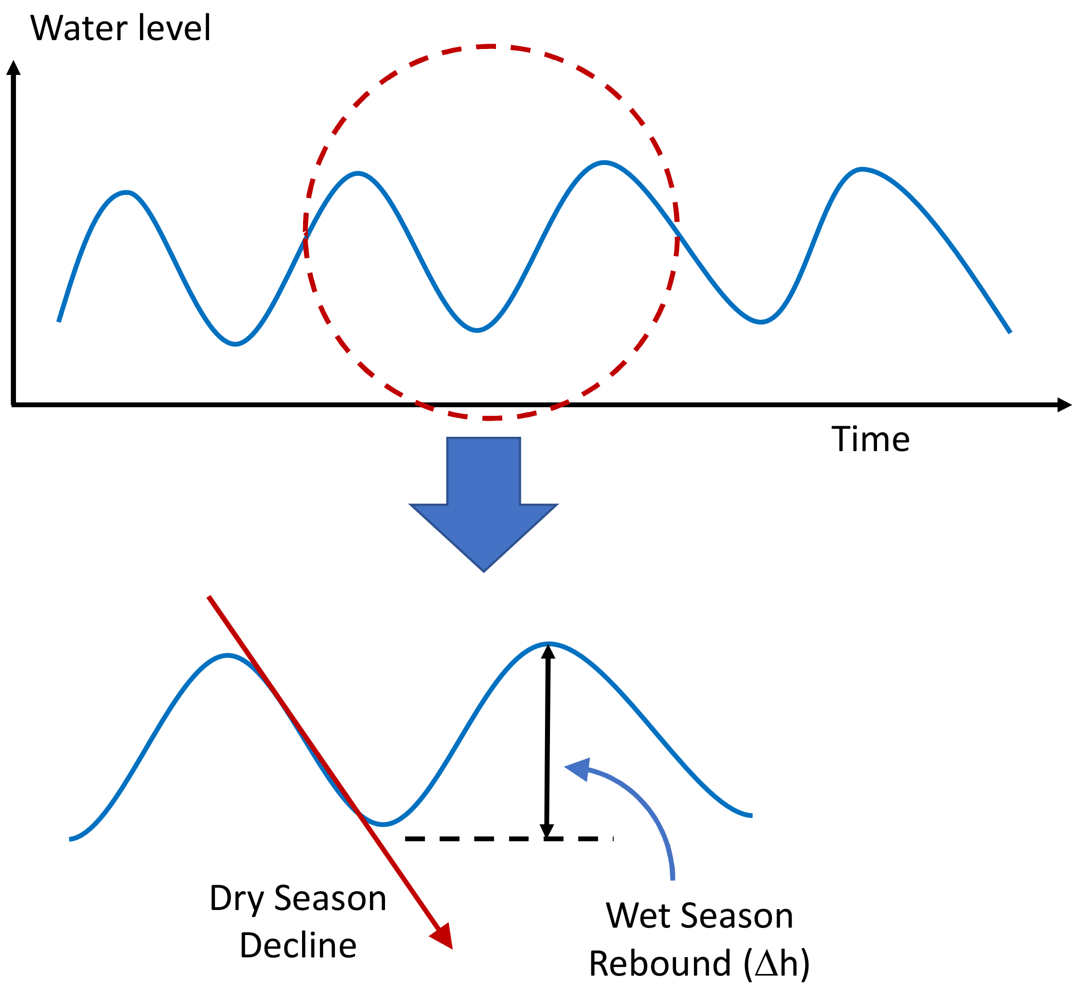
Background

- Method for estimating recharge from cyclic (seasonal) water table fluctuations
- Assumes gains during wet season are correlated to recharge
- Typically applied to water levels from wells, but can be derived from GRACE-derived groundwater levels



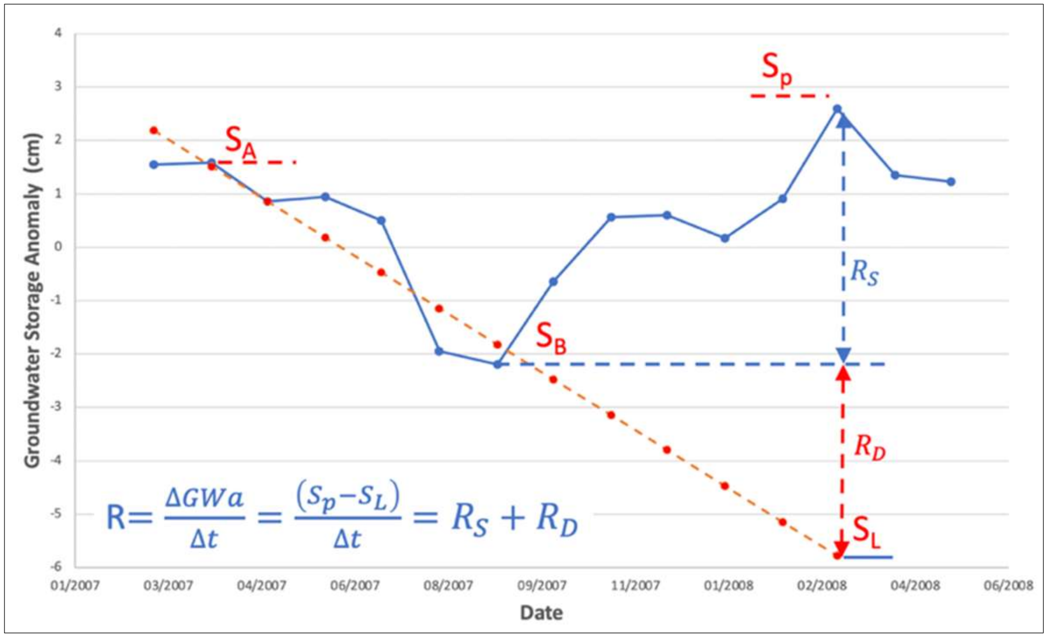


Using water levels from wells:

$$R = S_y\left(\frac{\Delta h}{t}\right)$$

Using water levels from GRACE:

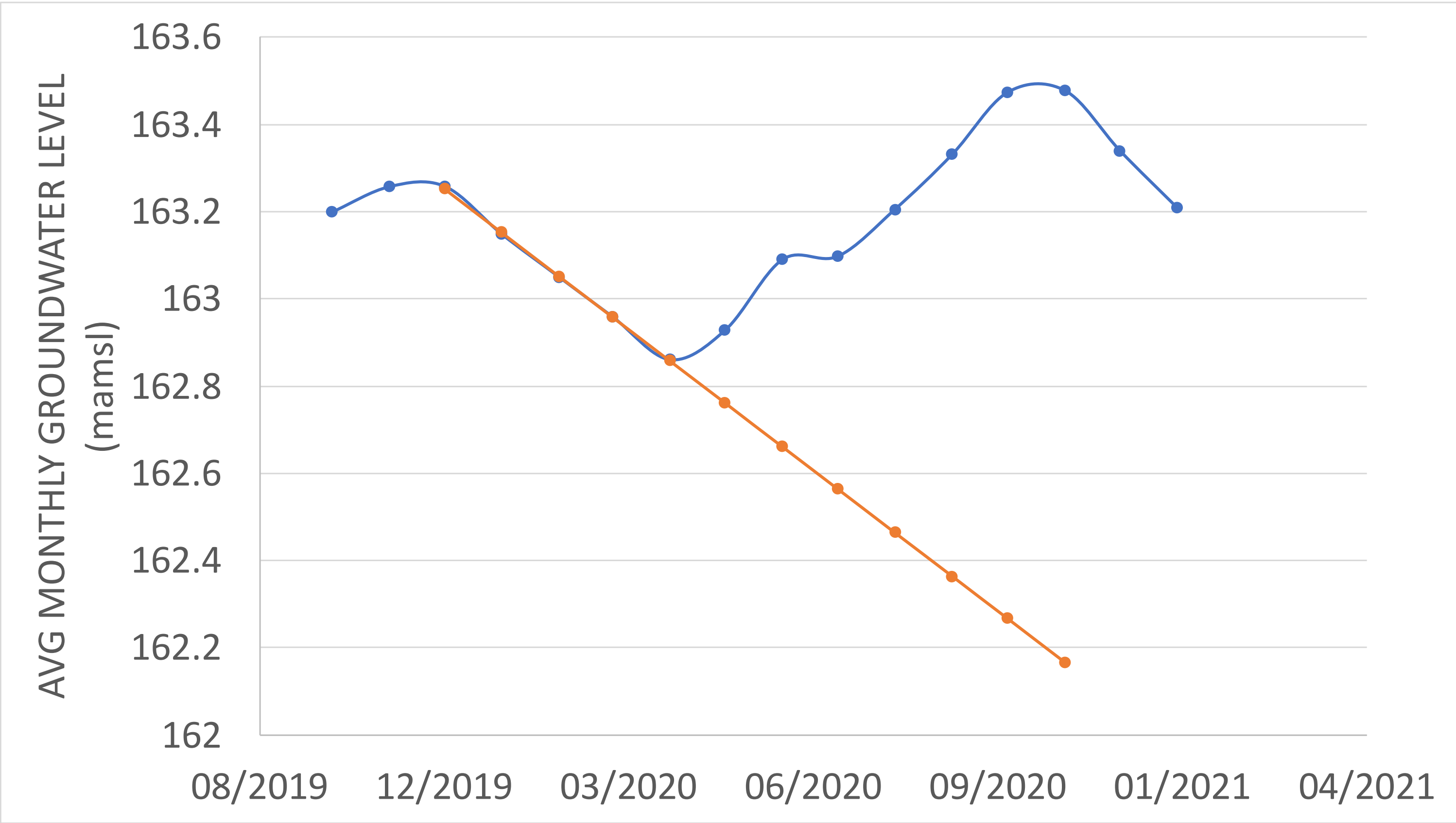
$$R = \frac{\Delta \mathrm{GWSa}}{\Delta t}$$



$$R_{method\ 1} = \frac{\Delta \text{GWSa}}{\Delta t} = \frac{S_p - S_B}{\Delta t} = R_S$$

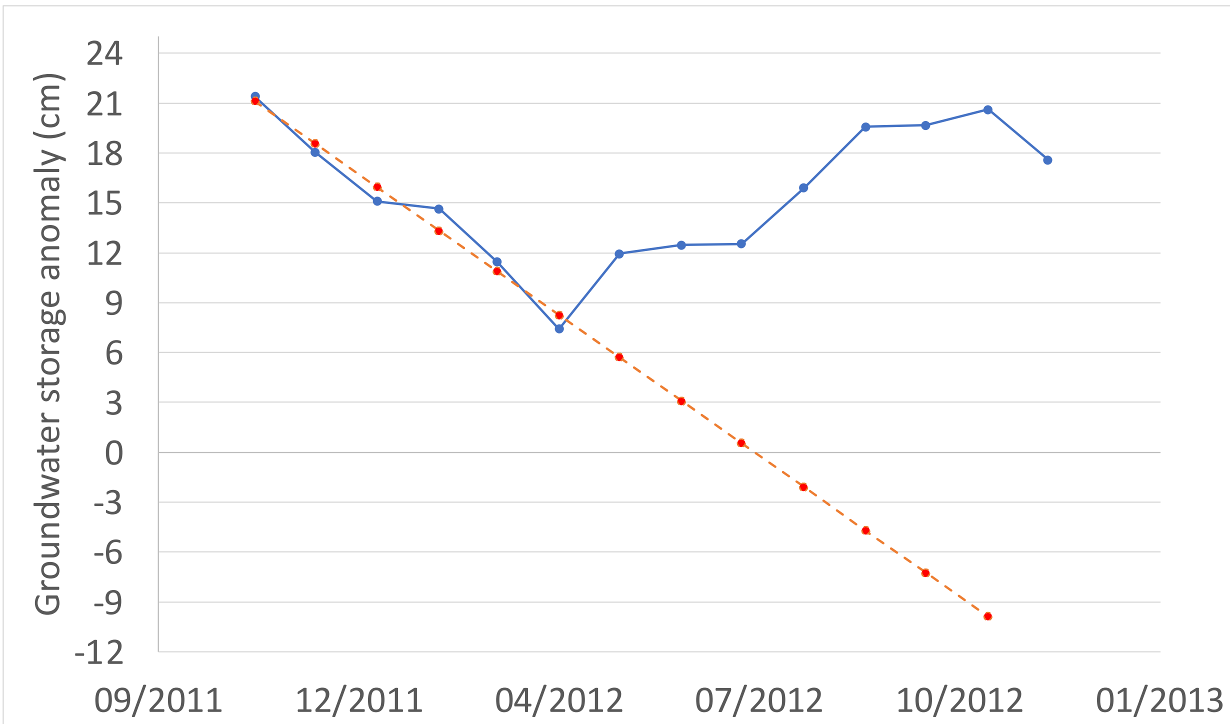
$$R_{metho\ \ 2} = \frac{\Delta \text{GWSa}}{\Delta t} = \frac{S_p - S_L}{\Delta t} = R_S + R_D$$

WTF method– for in situ example



$$R = S_y \left(\frac{\Delta h}{t}\right)$$

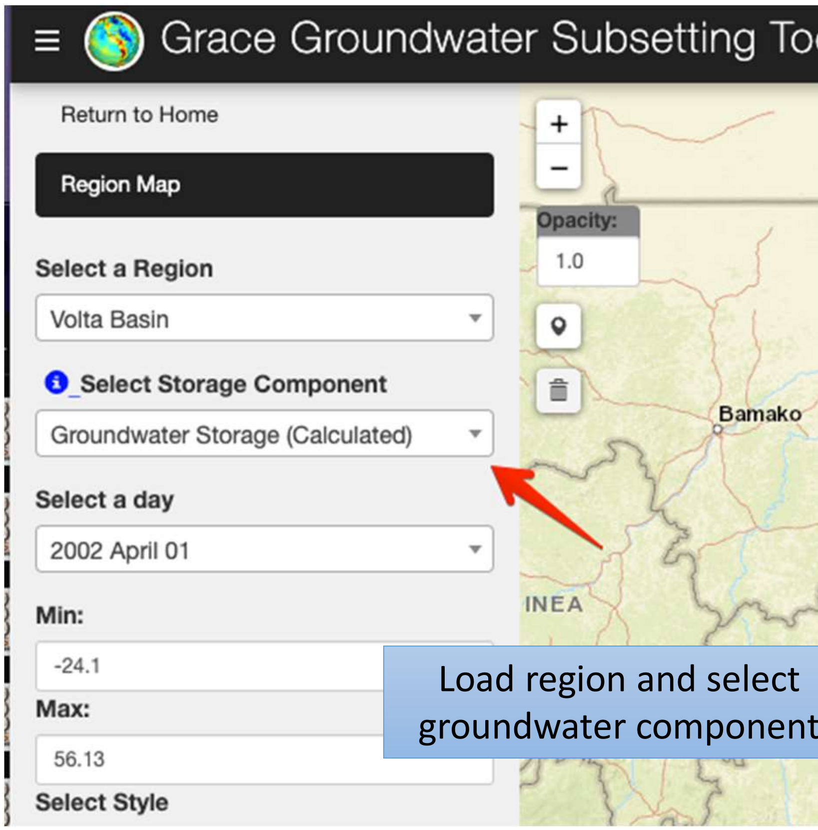
WTF method – GRACE example



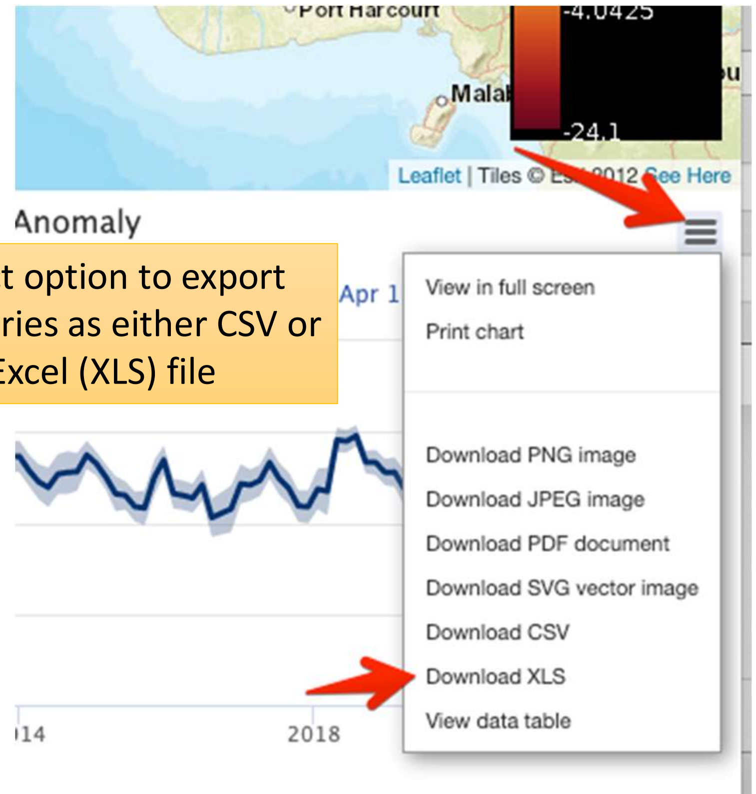
$$R_{meth\quad 1} = R_S$$

$$R_{meth\quad 2} = R_S + R_D$$

Getting Water Level Time Series from GGST



Load region and select groundwater component



Select option to export time series as either CSV or Excel (XLS) file

Getting Water Level Time Series from GGST

{x}

Function 3: getRegionTimeseries

```
[ ] #@markdown ### **Set inputs for getRegionTimeseries then run the cell
    F3_Storage_Option = "gw" #@param ["gw", "sm", "sw", "swe", "tws", "ca
    # Initialize timeseries request. API Token is passed in the headers i
    # Name and Storage Type parameters are passed in the data dictionary
    storage_type = F3_Storage_Option
    data_obj = {"name": region_name,
                "storage_type": storage_type}
    region_timeseries_request = requests.post(portal + "/apps/ggst/api/ge
                                              headers={"Authorization": i
                                              data = data_obj,
                                              files= region_files)
```

Set inputs for getRegionTimeseries then run the cell to run the function

F3_Storage_Option: gw

```
[ ] #@markdown ### **Run this cell to convert the request to a dataframe

    # Get the json object from the request
    region_ts_json = region_timeseries_request.json()
    # Create a dataframe from the JSON for plotting
    region_ts = (pandas.DataFrame(columns=["date", "ts"], data=region_ts_
                 .merge(pandas.DataFrame(columns=["date", "error_min", "er
    region_ts["date"] =  pandas.to_datetime(region_ts.date)
    region_ts
```

Run this cell to convert the request to a dataframe view the timeseries table

Can also be generated and exported from Google Colab API

```
[ ] #@markdown ### **Plot the dataframe with error range**
    fig, ax = plt.subplots(1, 1, figsize=(25,5))
    ax.plot(region_ts.date, region_ts.ts)
    ax.fill_between(region_ts.date, region_ts.error_min, region_ts.error_
    ax.set_title(region_name + ' Average ' + F3_Storage_Option +' Storage
```

Plot the dataframe with error range

Units on Exported File (from web app)

	A	B	C	D
1	Date	Groundwater Storage (Calculated)	Groundwater Storage (Calculated) Error Range (low)	Groundwater Storage (Calculated) Error Range (high)
2	1017619200000.00	-6.68	-18.99	5.64
3	1020211200000.00	-5.03	-11.75	1.68
4	1028160000000.00	-11.32	-15.81	-6.84
5	1030838400000.00	-5.27	-11.97	1.43
6	1033430400000.00	-2.46	-5.96	1.04
7	1036108800000.00	-4.25	-8.22	-0.27
8	1038700800000.00	-6.55	-10.69	-2.42
9	1041379200000.00	-2.35	-7.66	2.96
10	1044057600000.00	-4.07	-8.03	-0.11
11	1046476800000.00	-7.17	-10.09	-4.25
12	1049155200000.00	-7.65	-10.02	-5.27
13	1051747200000.00	-9.07	-11.38	-6.77
14	1057017600000.00	-8.68	-10.87	-6.49
15	1059696000000.00	-9.00	-10.78	-7.23
16	1062374400000.00	-1.42	-4.87	2.04

cm

cm

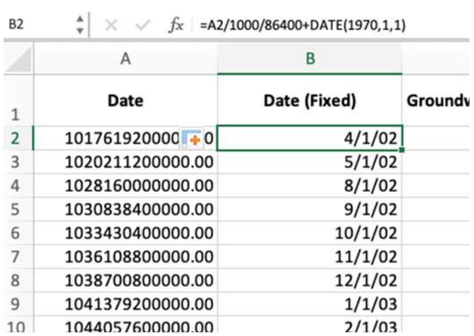
cm

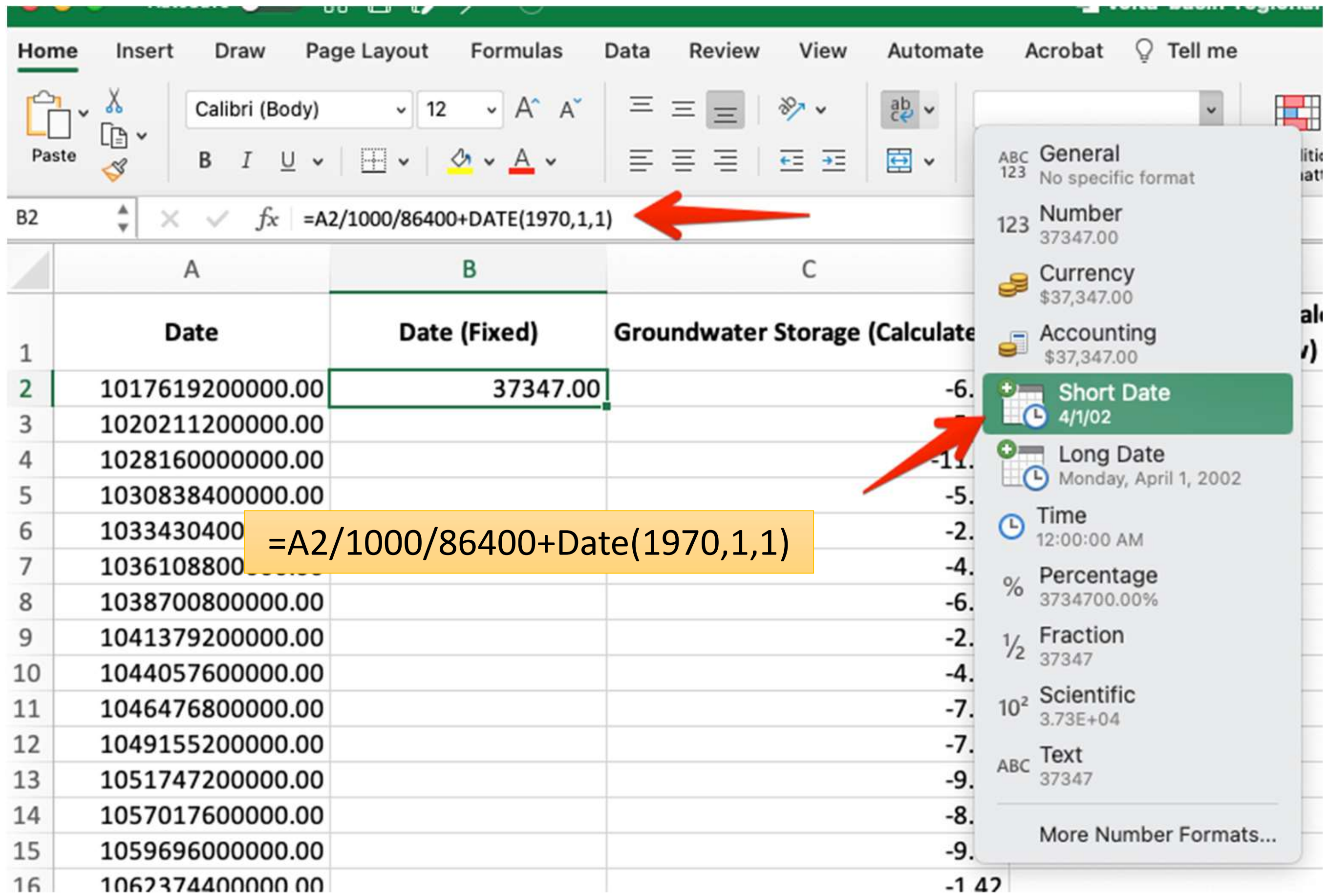
milliseconds since january 1, 1970

Fixing the Date Format

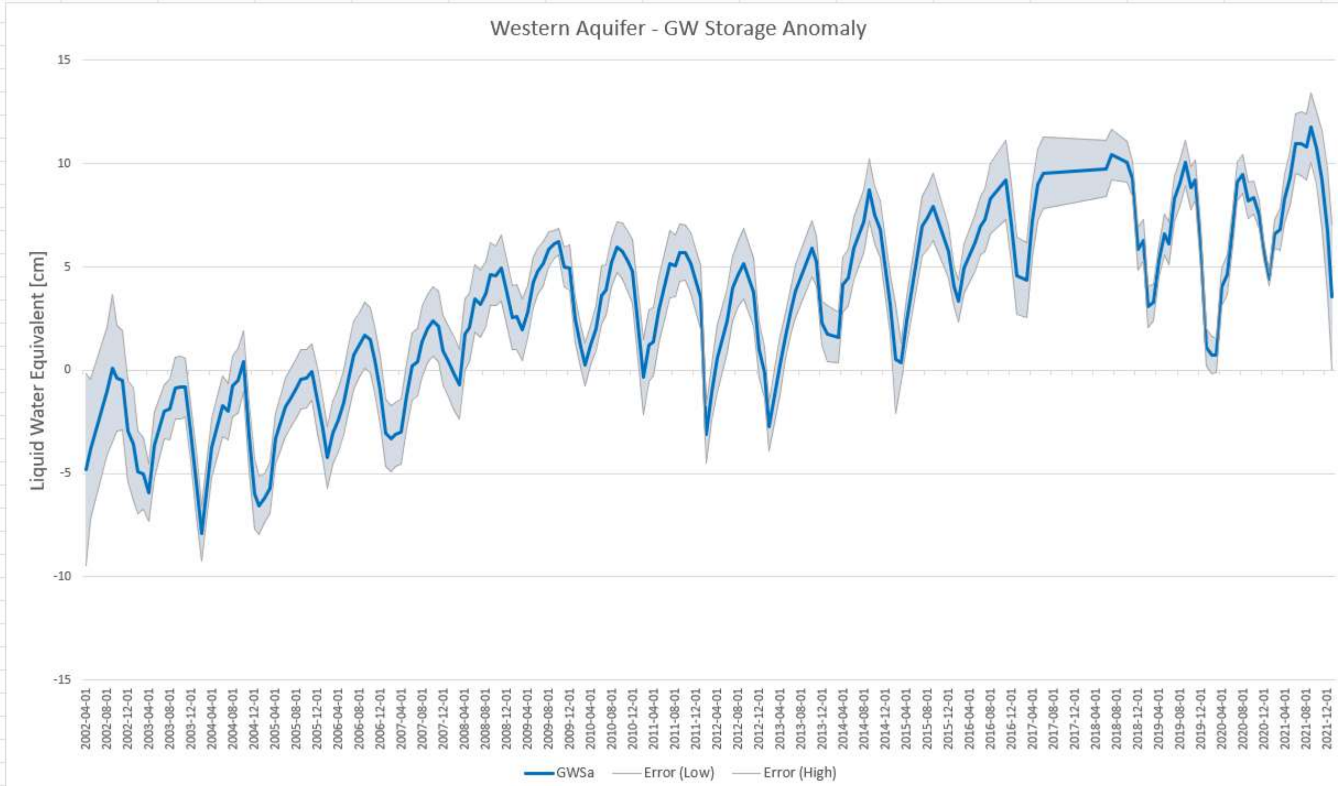
1) Create new column
2) Enter formula
3) Change to date format
4) Copy down

Result:





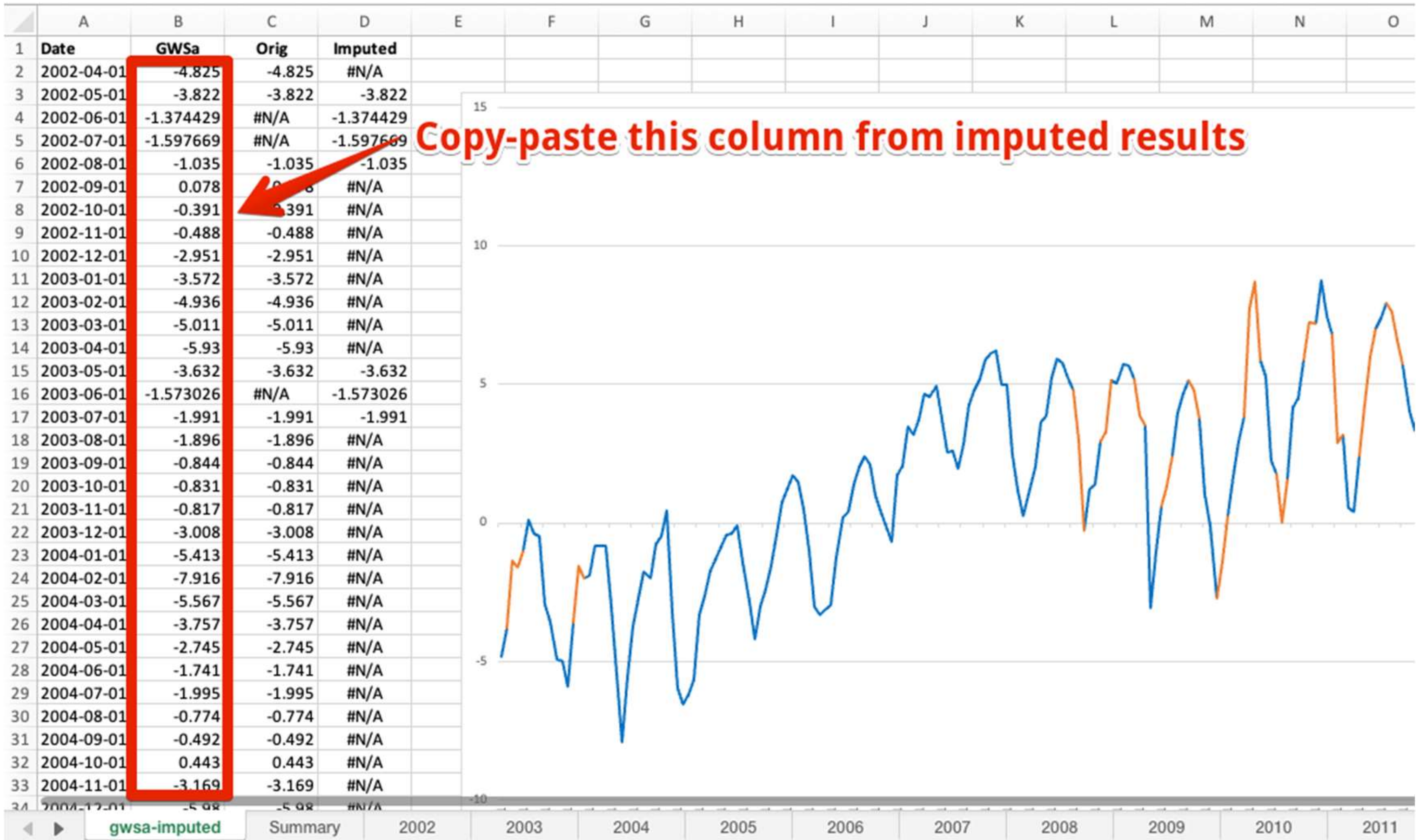
Date	GWSa	Error (Low)	Error (High)	Base	Difference
2002-04-01	-4.825	-9.464	-0.185	-9.464	9.279
2002-05-01	-3.822	-7.224	-0.421	-7.224	6.803
2002-08-01	-1.035	-4.13	2.06	-4.13	6.19
2002-09-01	0.078	-3.487	3.644	-3.487	7.131
2002-10-01	-0.391	-2.947	2.164	-2.947	5.111
2002-11-01	-0.488	-2.889	1.914	-2.889	4.803
2002-12-01	-2.951	-5.391	-0.51	-5.391	4.881
2003-01-01	-3.572	-6.28	-0.865	-6.28	5.415
2003-02-01	-4.936	-6.93	-2.943	-6.93	3.987
2003-03-01	-5.011	-6.741	-3.281	-6.741	3.46
2003-04-01	-5.93	-7.33	-4.529	-7.33	2.801
2003-05-01	-3.632	-5.246	-2.017	-5.246	3.229
2003-07-01	-1.991	-3.305	-0.676	-3.305	2.629
2003-08-01	-1.896	-3.355	-0.437	-3.355	2.918
2003-09-01	-0.844	-2.33	0.641	-2.33	2.971
2003-10-01	-0.831	-2.336	0.674	-2.336	3.01
2003-11-01	-0.817	-2.226	0.591	-2.226	2.817
2003-12-01	-3.008	-4.362	-1.653	-4.362	2.709
2004-01-01	-5.413	-6.97	-3.856	-6.97	3.114
2004-02-01	-7.916	-9.245	-6.587	-9.245	2.658
2004-03-01	-5.567	-6.927	-4.208	-6.927	2.719
2004-04-01	-3.757	-5.176	-2.337	-5.176	2.839
2004-05-01	-2.745	-4.205	-1.284	-4.205	2.921
2004-06-01	-1.741	-3.218	-0.265	-3.218	2.953
2004-07-01	-1.995	-3.366	-0.624	-3.366	2.742
2004-08-01	-0.774	-2.251	0.702	-2.251	2.953
2004-09-01	-0.492	-2.064	1.08	-2.064	3.144
2004-10-01	0.443	-1.036	1.923	-1.036	2.959
2004-11-01	-3.169	-4.799	-1.538	-4.799	3.261
2004-12-01	-5.98	-7.682	-4.277	-7.682	3.405
2005-01-01	-6.545	-7.937	-5.153	-7.937	2.784
2005-02-01	-6.202	-7.372	-5.033	-7.372	2.339
2005-03-01	-5.689	-6.947	-4.432	-6.947	2.515
2005-04-01	-3.333	-4.559	-2.107	-4.559	2.452
2005-05-01	-2.646	-3.962	-1.329	-3.962	2.633
2005-06-01	-1.784	-3.192	-0.375	-3.192	2.817
2005-07-01	-1.319	-2.733	0.095	-2.733	2.828
2005-08-01	-0.88	-2.327	0.567	-2.327	2.894
2005-09-01	-0.435	-1.876	1.005	-1.876	2.881



Copy to ***raw-clean.xlsx** Excel file for plotting/formatting the chart. See example in files provided.

After performing gap imputation (see other presentation), copy-paste imputed GWSa into *gwsa-wtf.xlsx Excel file in the main tab.

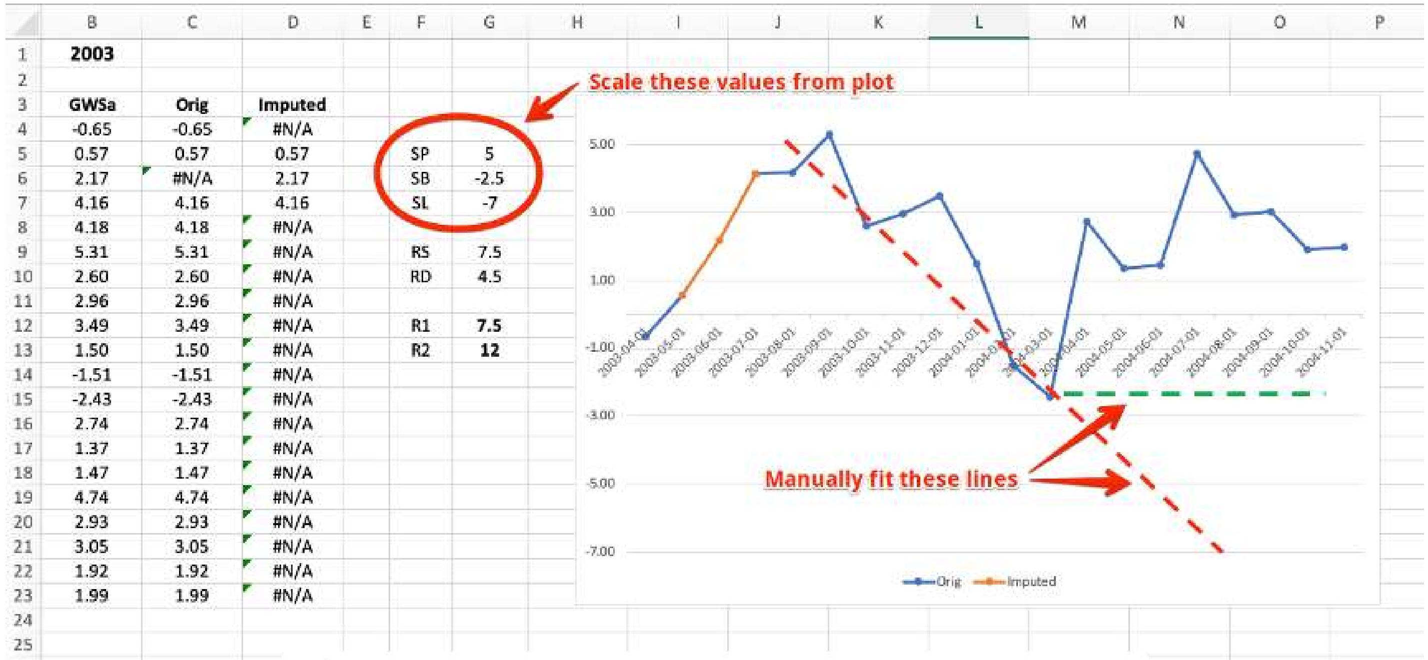
You may need to extend additional rows at the bottom of the table and adjust the chart if you have results for additional dates.



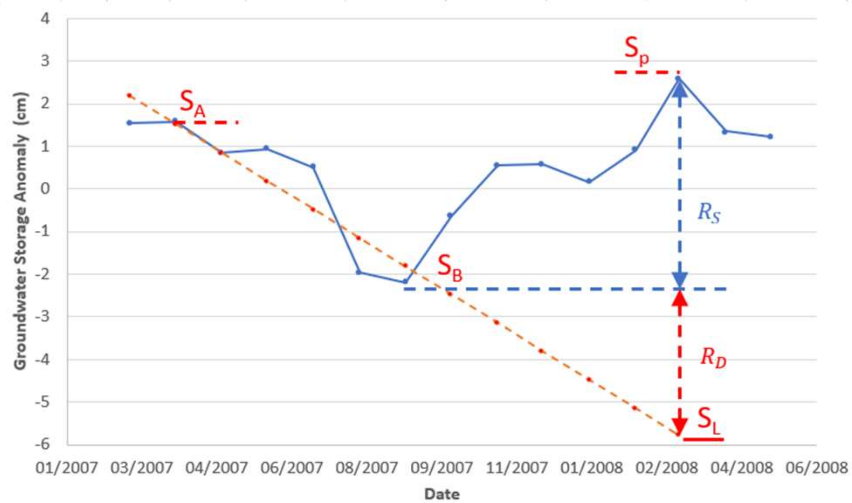
	Date	GWSa	Orig	Imputed
2	2002-04-01	-4.825	-4.825	#N/A
3	2002-05-01	-3.822	-3.822	-3.822
4	2002-06-01	-1.374429	#N/A	-1.374429
5	2002-07-01	-1.597669	#N/A	-1.597669
6	2002-08-01	-1.035	-1.035	-1.035
7	2002-09-01	0.078	[illegible]	#N/A
8	2002-10-01	-0.391	[illegible]	#N/A
9	2002-11-01	-0.488	-0.488	#N/A
10	2002-12-01	-2.951	-2.951	#N/A
11	2003-01-01	-3.572	-3.572	#N/A
12	2003-02-01	-4.936	-4.936	#N/A
13	2003-03-01	-5.011	-5.011	#N/A
14	2003-04-01	-5.93	-5.93	#N/A
15	2003-05-01	-3.632	-3.632	-3.632
16	2003-06-01	-1.573026	#N/A	-1.573026
17	2003-07-01	-1.991	-1.991	-1.991
18	2003-08-01	-1.896	-1.896	#N/A
19	2003-09-01	-0.844	-0.844	#N/A
20	2003-10-01	-0.831	-0.831	#N/A
21	2003-11-01	-0.817	-0.817	#N/A
22	2003-12-01	-3.008	-3.008	#N/A
23	2004-01-01	-5.413	-5.413	#N/A
24	2004-02-01	-7.916	-7.916	#N/A
25	2004-03-01	-5.567	-5.567	#N/A
26	2004-04-01	-3.757	-3.757	#N/A
27	2004-05-01	-2.745	-2.745	#N/A
28	2004-06-01	-1.741	-1.741	#N/A
29	2004-07-01	-1.995	-1.995	#N/A
30	2004-08-01	-0.774	-0.774	#N/A
31	2004-09-01	-0.492	-0.492	#N/A
32	2004-10-01	0.443	0.443	#N/A
33	2004-11-01	-3.169	-3.169	#N/A
34	2004-12-01	-5.98	-5.98	#N/A

At this point you can browse through each of the tabs for the years starting in 2002.

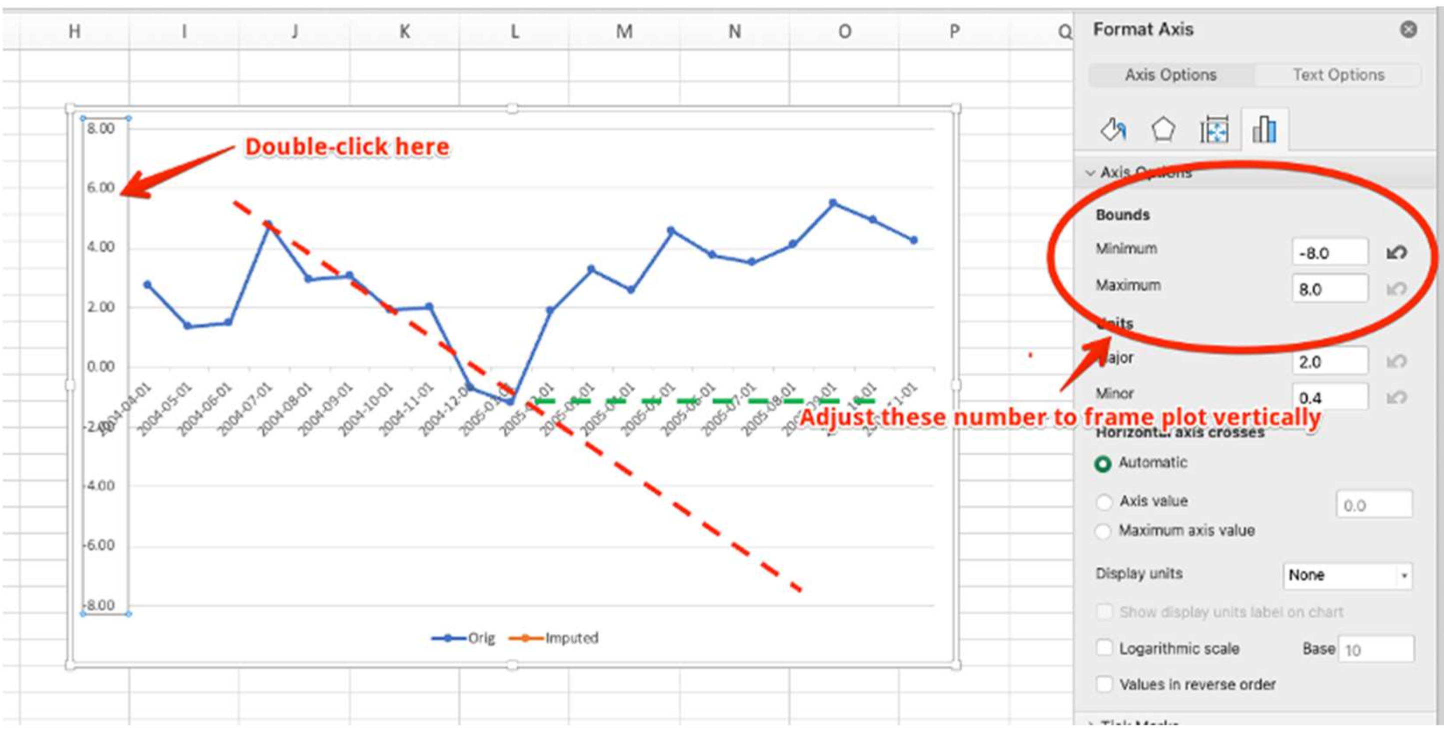
For each page, manually adjust the red and green lines to fit the descending branch and the base. Then manually scale off the SP, SB, and SL values in cm from the vertical axis and enter into the three cells indicated in the diagram. The RS, RD, R1, and R2 values will then be automatically calculated.



	B	C	D	E	F	G
1	2003					
2						
3	GWSa	Orig	Imputed			
4	-0.65	-0.65	#N/A			
5	0.57	0.57	0.57		SP	5
6	2.17	#N/A	2.17		SB	-2.5
7	4.16	4.16	4.16		SL	-7
8	4.18	4.18	#N/A			
9	5.31	5.31	#N/A		RS	7.5
10	2.60	2.60	#N/A		RD	4.5
11	2.96	2.96	#N/A			
12	3.49	3.49	#N/A		R1	7.5
13	1.50	1.50	#N/A		R2	12
14	-1.51	-1.51	#N/A			
15	-2.43	-2.43	#N/A			
16	2.74	2.74	#N/A			
17	1.37	1.37	#N/A			
18	1.47	1.47	#N/A			
19	4.74	4.74	#N/A			
20	2.93	2.93	#N/A			
21	3.05	3.05	#N/A			
22	1.92	1.92	#N/A			
23	1.99	1.99	#N/A			
24						
25						



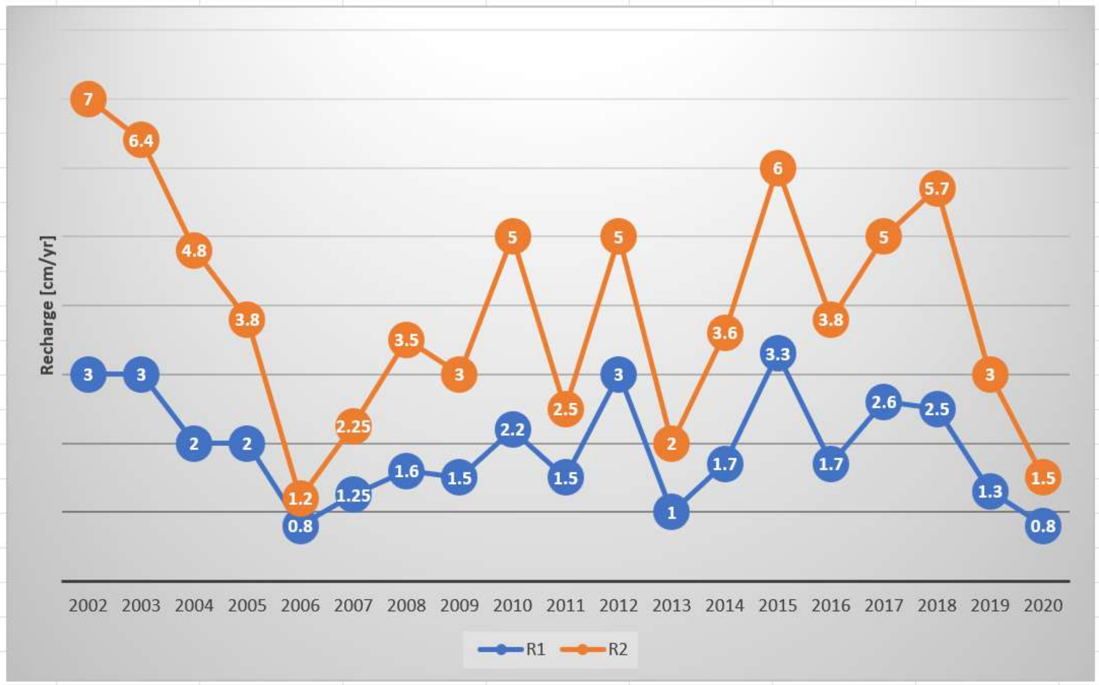
As you examine the plot for each year, you may need to adjust the range of the vertical axis before you can properly fit the lines. To do this, double-click on the vertical axis, click on the axis options tab, and manually adjust the minimum and maximum bounds to properly frame the plot.



After processing all of the years and calculating all of the R1, R2 values, you can see a summary in the Summary sheet.

Recharge Rate Sumary

Year	R1	R2
2002	3	7
2003	3	6.4
2004	2	4.8
2005	2	3.8
2006	0.8	1.2
2007	1.25	2.25
2008	1.6	3.5
2009	1.5	3
2010	2.2	5
2011	1.5	2.5
2012	3	5
2013	1	2
2014	1.7	3.6
2015	3.3	6
2016	1.7	3.8
2017	2.6	5
2018	2.5	5.7
2019	1.3	3
2020	0.8	1.5
Mean	**1.9**	**4.0**



Questions?