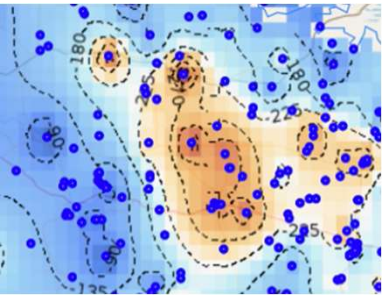
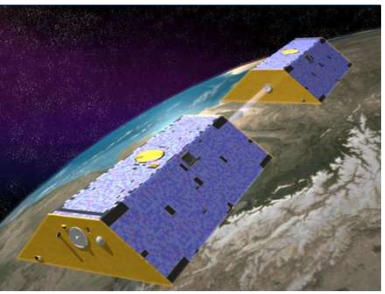
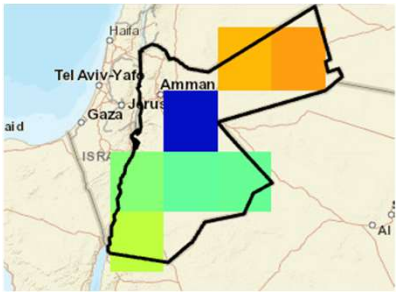
Performing a GGST Analysis at a Selected Point

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







UNITED NATIONS
الاسكوا
ESCWA

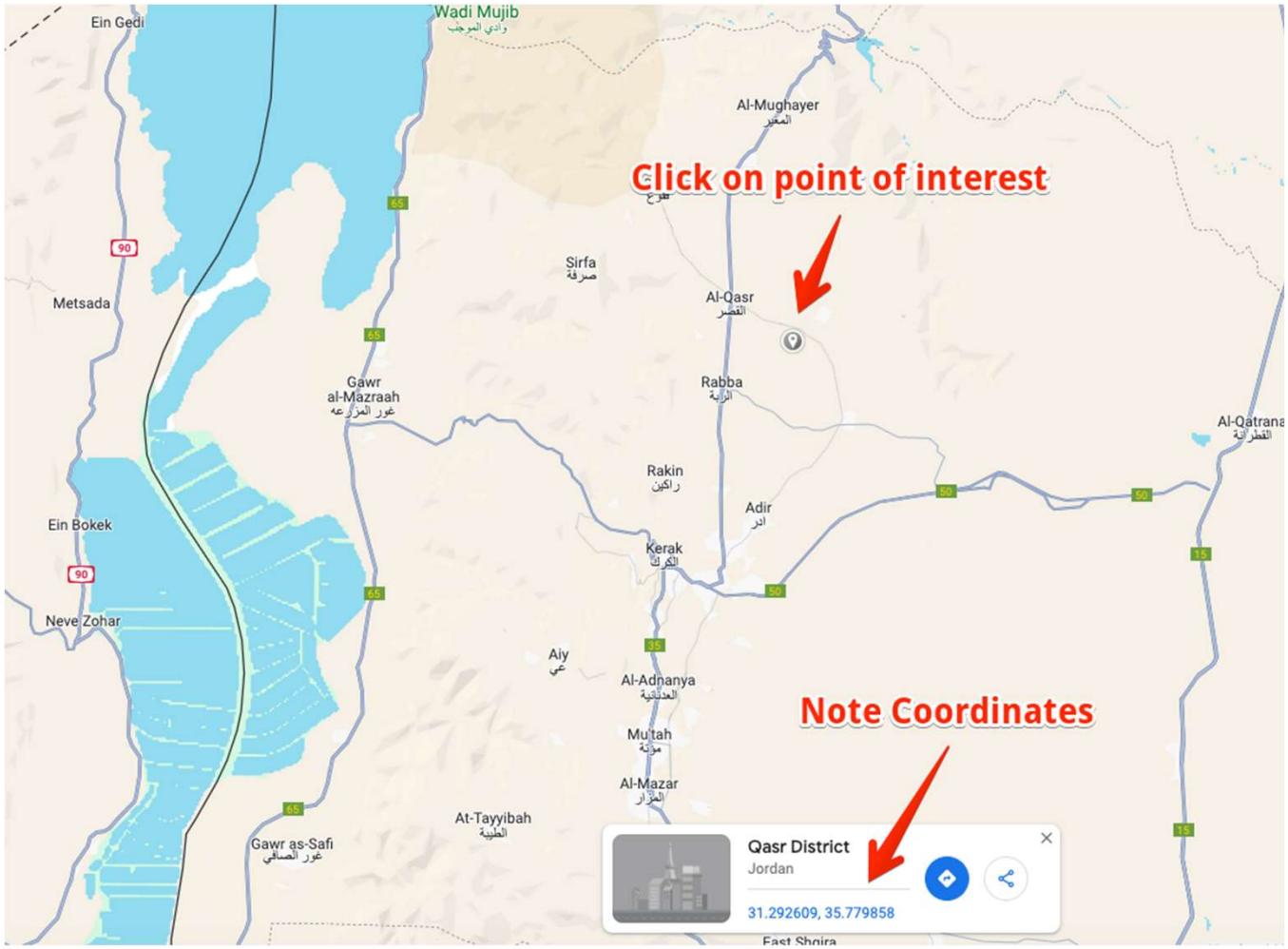
Shared Prosperity Dignified Life

Sweden
Sverige

Main Steps

1) Use mapping software to find lat-lon coordinates of point of interest
2) Run API Colab script to create CSV file with point time series
3) Create copy with just date and GWSa columns
4) Run imputation script to fill in gaps
5) Copy data to WTF worksheet to find recharge rates

1) Find lat-lon coordinates

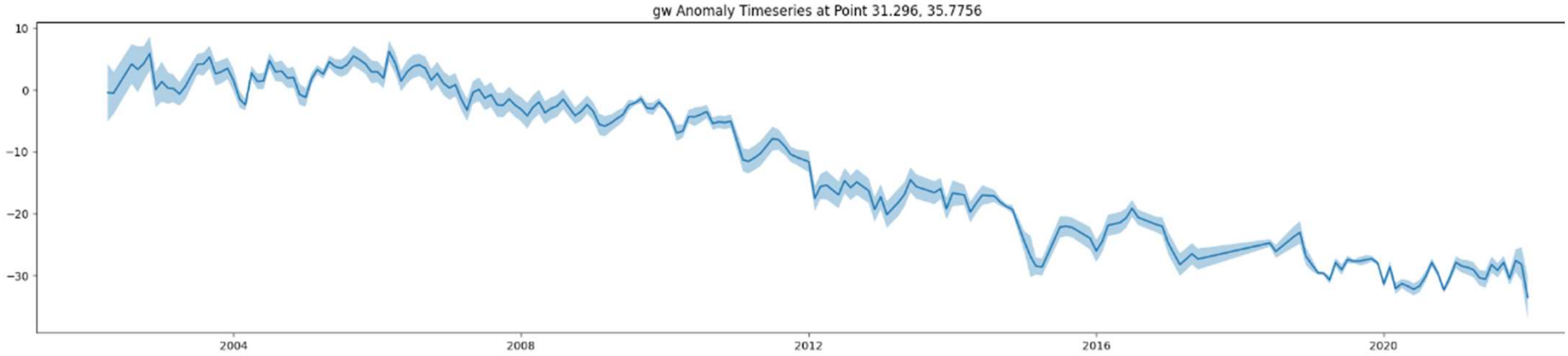


2) Run API Script

```
#@markdown ### **Run this cell to plot the dataframe**
# Plot the dataframe with error range
fig, ax = plt.subplots(1, 1, figsize=(25,5))
ax.plot(point_ts.date, point_ts.ts)
ax.fill_between(point_ts.date, point_ts.error_min, point_ts.error_max, a
ax.set_title(F2_Storage_Option+' Anomaly Timeseries at Point ' +Lat+', '
```

Run this cell to plot the dataframe

```
Text(0.5, 1.0, 'gw Anomaly Timeseries at Point 31.296, 35.7756')
```



Export CSV file with GWSa time series

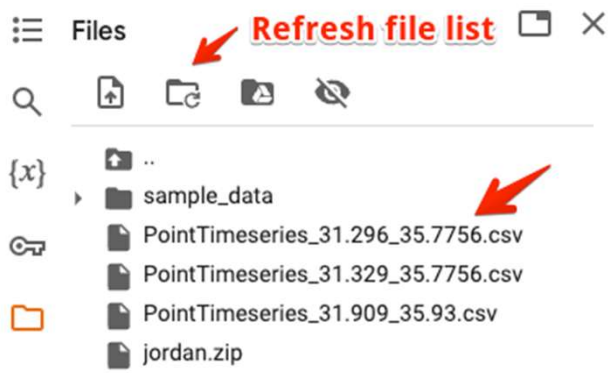
(1)

```
#@markdown ### **Run this cell to create timeseries CSV**
#@markdown  You can download the CSV from the files panel on the left si
#Export timeseries to CSV
point_ts.to_csv('PointTimeseries_'+Lat+'_'+Lon+".csv")
```

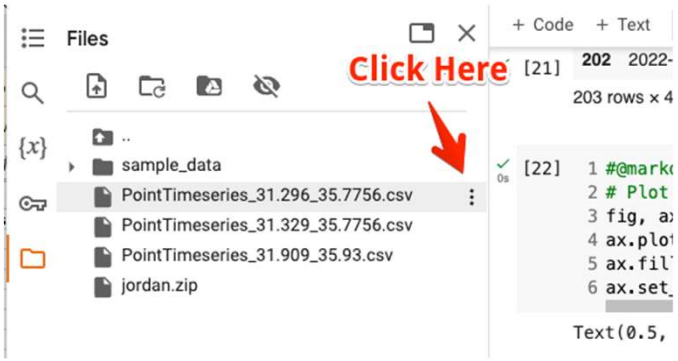
Run this cell to create timeseries CSV

You can download the CSV from the files panel on the left side of the window

(2)



(3)

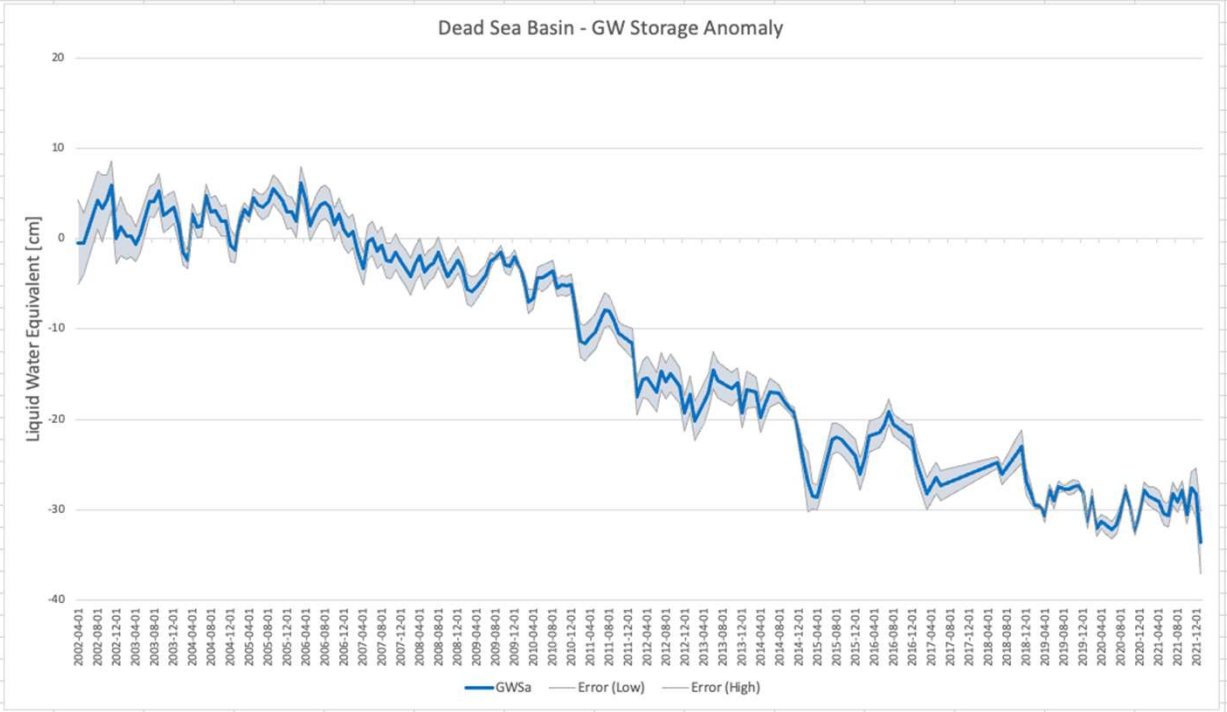


(4) Select “Download” option from list

Open in Excel and Chart Results

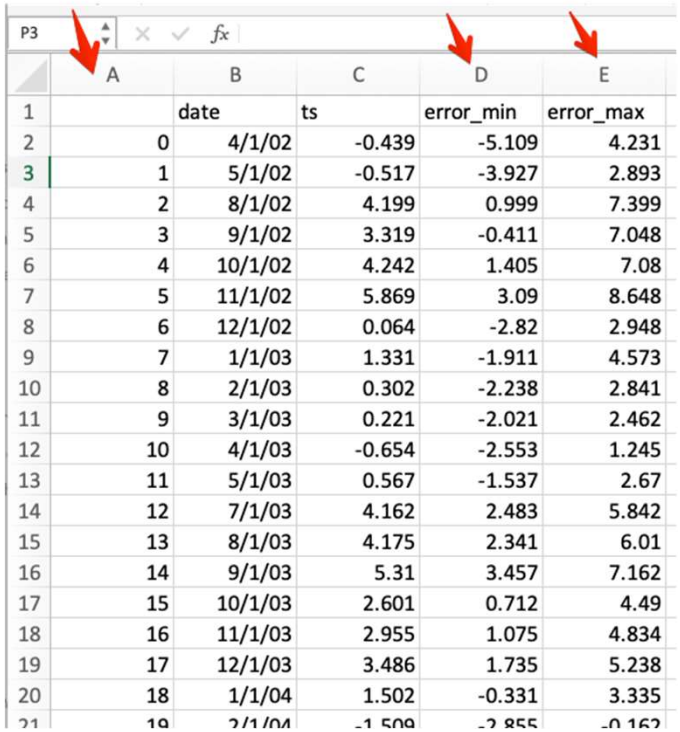
Dates exported from the API script do not need to be converted.

Date	GWSa	Error (Low)	Error (High)	Base	Difference
2002-04-01	-0.439	-5.109	4.231	-5.109	9.34
2002-05-01	-0.517	-3.927	2.893	-3.927	6.82
2002-08-01	4.199	0.999	7.399	0.999	6.4
2002-09-01	3.319	-0.411	7.048	-0.411	7.459
2002-10-01	4.242	1.405	7.08	1.405	5.675
2002-11-01	5.869	3.09	8.648	3.09	5.558
2002-12-01	0.064	-2.82	2.948	-2.82	5.768
2003-01-01	1.331	-1.911	4.573	-1.911	6.484
2003-02-01	0.302	-2.238	2.841	-2.238	5.079
2003-03-01	0.221	-2.021	2.462	-2.021	4.483
2003-04-01	-0.654	-2.553	1.245	-2.553	3.798
2003-05-01	0.567	-1.537	2.67	-1.537	4.207
2003-07-01	4.162	2.483	5.842	2.483	3.359
2003-08-01	4.175	2.341	6.01	2.341	3.669
2003-09-01	Paste data here		7.162	3.457	3.705
2003-10-01	2.601	0.712	4.49	0.712	3.778
2003-11-01	2.955	1.075	4.834	1.075	3.759
2003-12-01	3.486	1.735	5.238	1.735	3.503
2004-01-01	1.502	-0.331	3.335	-0.331	3.666
2004-02-01	-1.509	-2.855	-0.162	-2.855	2.693
2004-03-01	-2.434	-3.355	-1.513	-3.355	1.842
2004-04-01	2.741	1.646	3.837	1.646	2.191
2004-05-01	1.368	0.112	2.624	0.112	2.512
2004-06-01	1.467	0.135	2.799	0.135	2.664
2004-07-01	4.741	3.502	5.98	3.502	2.478
2004-08-01	2.925	1.39	4.46	1.39	3.07
2004-09-01	3.046	1.316	4.776	1.316	3.46
2004-10-01	1.924	0.295	3.552	0.295	3.257
2004-11-01	1.991	0.3	3.681	0.3	3.381
2004-12-01	-0.731	-2.47	1.008	-2.47	3.478
2005-01-01	-1.211	-2.676	0.254	-2.676	2.93
2005-02-01	1.87	0.876	2.863	0.876	1.987
2005-03-01	3.263	2.495	4.032	2.495	1.537
2005-04-01	2.555	1.78	3.33	1.78	1.55
2005-05-01	4.568	3.574	5.563	3.574	1.989
2005-06-01	3.741	2.527	4.956	2.527	2.429
2005-07-01	3.496	2.086	4.905	2.086	2.819
2005-08-01	4.123	2.553	5.693	2.553	3.14
2005-09-01	5.474	3.844	7.103	3.844	3.259



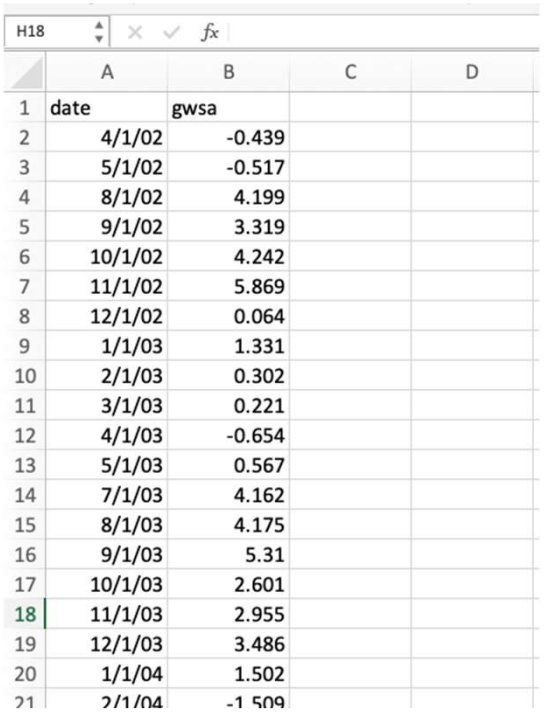
example: dsb-gwsa-raw-clean.xlsx

3) Create copy with just date and GWSa columns



	A	B	C	D	E
1		date	ts	error_min	error_max
2	0	4/1/02	-0.439	-5.109	4.231
3	1	5/1/02	-0.517	-3.927	2.893
4	2	8/1/02	4.199	0.999	7.399
5	3	9/1/02	3.319	-0.411	7.048
6	4	10/1/02	4.242	1.405	7.08
7	5	11/1/02	5.869	3.09	8.648
8	6	12/1/02	0.064	-2.82	2.948
9	7	1/1/03	1.331	-1.911	4.573
10	8	2/1/03	0.302	-2.238	2.841
11	9	3/1/03	0.221	-2.021	2.462
12	10	4/1/03	-0.654	-2.553	1.245
13	11	5/1/03	0.567	-1.537	2.67
14	12	7/1/03	4.162	2.483	5.842
15	13	8/1/03	4.175	2.341	6.01
16	14	9/1/03	5.31	3.457	7.162
17	15	10/1/03	2.601	0.712	4.49
18	16	11/1/03	2.955	1.075	4.834
19	17	12/1/03	3.486	1.735	5.238
20	18	1/1/04	1.502	-0.331	3.335
21	19	2/1/04	-1.509	-2.855	-0.162

Delete these columns



	A	B	C	D
1	date	gwsa		
2	4/1/02	-0.439		
3	5/1/02	-0.517		
4	8/1/02	4.199		
5	9/1/02	3.319		
6	10/1/02	4.242		
7	11/1/02	5.869		
8	12/1/02	0.064		
9	1/1/03	1.331		
10	2/1/03	0.302		
11	3/1/03	0.221		
12	4/1/03	-0.654		
13	5/1/03	0.567		
14	7/1/03	4.162		
15	8/1/03	4.175		
16	9/1/03	5.31		
17	10/1/03	2.601		
18	11/1/03	2.955		
19	12/1/03	3.486		
20	1/1/04	1.502		
21	2/1/04	-1.509		

Save as new CSV file

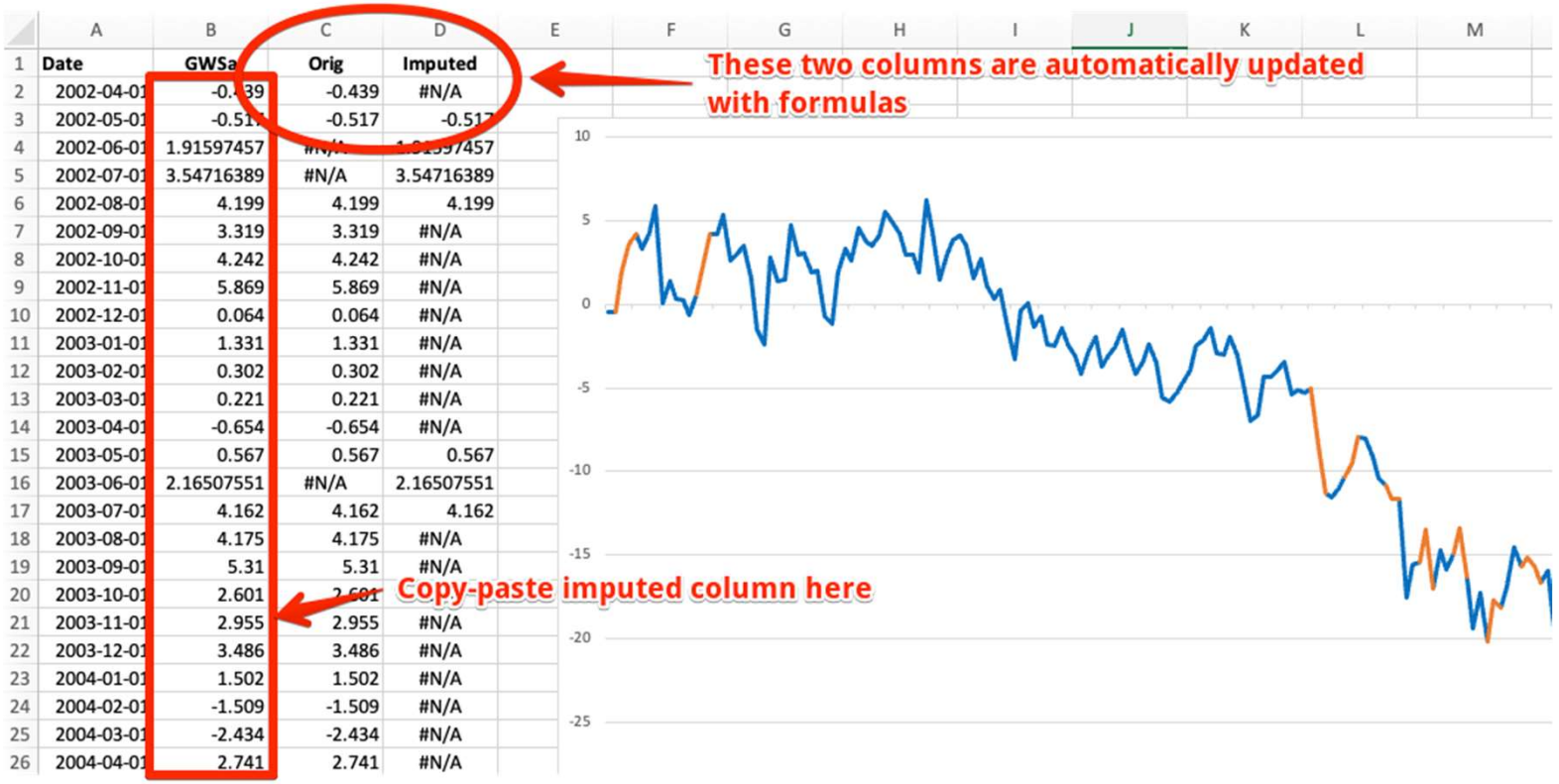
example: dsb-gwsa-raw-clean.csv

4) Run gap imputation script, save to new CSV


```
0s
1 # Export and Download file
2 grace_df_total_v2.to_csv("completed.csv")
3 files.download('completed.csv')
```

example: dsb-gwsa-imputed.csv

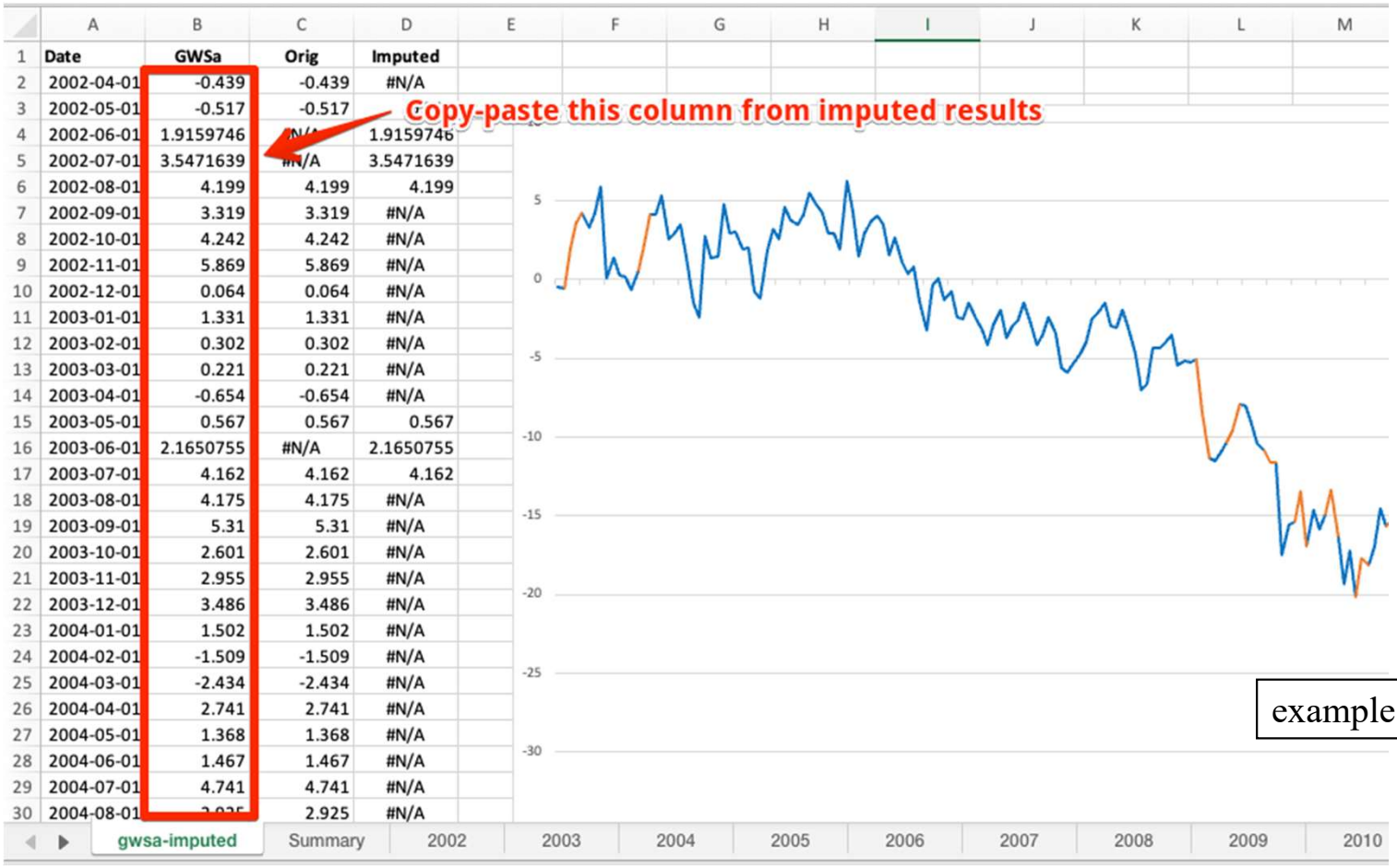
Optional – Plot imputed results in Excel



	Date	GWSa	Orig	Imputed
2	2002-04-01	-0.439	-0.439	#N/A
3	2002-05-01	-0.517	-0.517	-0.517
4	2002-06-01	1.91597457	#N/A	1.91597457
5	2002-07-01	3.54716389	#N/A	3.54716389
6	2002-08-01	4.199	4.199	4.199
7	2002-09-01	3.319	3.319	#N/A
8	2002-10-01	4.242	4.242	#N/A
9	2002-11-01	5.869	5.869	#N/A
10	2002-12-01	0.064	0.064	#N/A
11	2003-01-01	1.331	1.331	#N/A
12	2003-02-01	0.302	0.302	#N/A
13	2003-03-01	0.221	0.221	#N/A
14	2003-04-01	-0.654	-0.654	#N/A
15	2003-05-01	0.567	0.567	0.567
16	2003-06-01	2.16507551	#N/A	2.16507551
17	2003-07-01	4.162	4.162	4.162
18	2003-08-01	4.175	4.175	#N/A
19	2003-09-01	5.31	5.31	#N/A
20	2003-10-01	2.601	2.601	#N/A
21	2003-11-01	2.955	2.955	#N/A
22	2003-12-01	3.486	3.486	#N/A
23	2004-01-01	1.502	1.502	#N/A
24	2004-02-01	-1.509	-1.509	#N/A
25	2004-03-01	-2.434	-2.434	#N/A
26	2004-04-01	2.741	2.741	#N/A

example: dsb-gwsa-imputed.xlsx

5) Copy data to WTF worksheet to find recharge rates

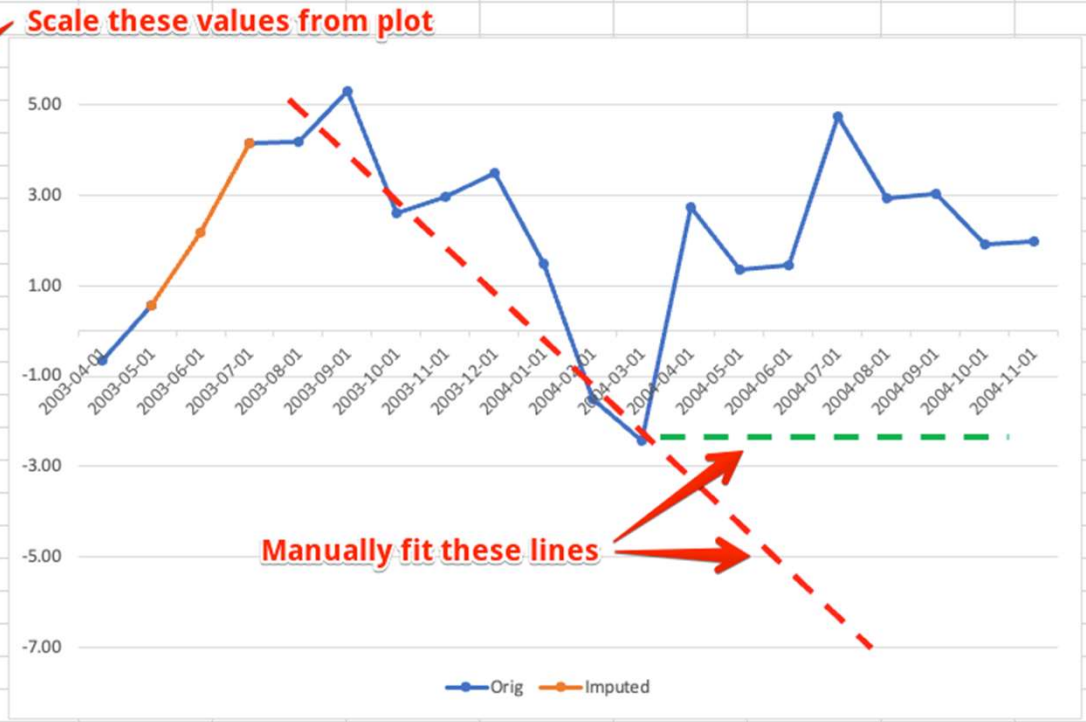


	A	B	C	D
1	Date	GWSa	Orig	Imputed
2	2002-04-01	-0.439	-0.439	#N/A
3	2002-05-01	-0.517	-0.517	#N/A
4	2002-06-01	1.9159746	#N/A	1.9159746
5	2002-07-01	3.5471639	#N/A	3.5471639
6	2002-08-01	4.199	4.199	4.199
7	2002-09-01	3.319	3.319	#N/A
8	2002-10-01	4.242	4.242	#N/A
9	2002-11-01	5.869	5.869	#N/A
10	2002-12-01	0.064	0.064	#N/A
11	2003-01-01	1.331	1.331	#N/A
12	2003-02-01	0.302	0.302	#N/A
13	2003-03-01	0.221	0.221	#N/A
14	2003-04-01	-0.654	-0.654	#N/A
15	2003-05-01	0.567	0.567	0.567
16	2003-06-01	2.1650755	#N/A	2.1650755
17	2003-07-01	4.162	4.162	4.162
18	2003-08-01	4.175	4.175	#N/A
19	2003-09-01	5.31	5.31	#N/A
20	2003-10-01	2.601	2.601	#N/A
21	2003-11-01	2.955	2.955	#N/A
22	2003-12-01	3.486	3.486	#N/A
23	2004-01-01	1.502	1.502	#N/A
24	2004-02-01	-1.509	-1.509	#N/A
25	2004-03-01	-2.434	-2.434	#N/A
26	2004-04-01	2.741	2.741	#N/A
27	2004-05-01	1.368	1.368	#N/A
28	2004-06-01	1.467	1.467	#N/A
29	2004-07-01	4.741	4.741	#N/A
30	2004-08-01	2.925	2.925	#N/A

example: dsb-gwsa-wtf.xlsx

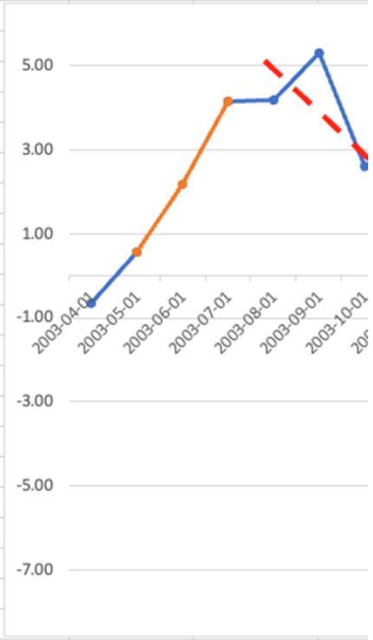
Perform WTF curve fitting for each year

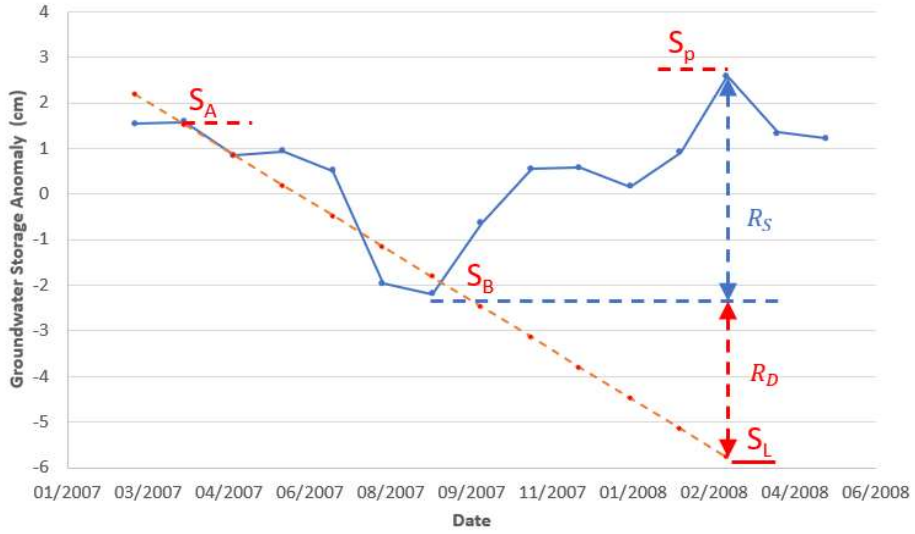
	B	C	D	F	G
1	**2003**				
2					
3	**GWSa**	**Orig**	**Imputed**		
4	-0.65	-0.65	#N/A		
5	0.57	0.57	0.57	SP	5
6	2.17	#N/A	2.17	SB	-2.5
7	4.16	4.16	4.16	SL	-7
8	4.18	4.18	#N/A		
9	5.31	5.31	#N/A	RS	7.5
10	2.60	2.60	#N/A	RD	4.5
11	2.96	2.96	#N/A		
12	3.49	3.49	#N/A	R1	**7.5**
13	1.50	1.50	#N/A	R2	**12**
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		



R1, R2 automatically updated

2003				
GWSa	Orig	Imputed		
-0.65	-0.65	#N/A		
0.57	0.57	0.57	SP	5
2.17	#N/A	2.17	SB	-2.5
4.16	4.16	4.16	SL	-7
4.18	4.18	#N/A		
5.31	5.31	#N/A	RS	7.5
2.60	2.60	#N/A	RD	4.5
2.96	2.96	#N/A		
3.49	3.49	#N/A	R1	**7.5**
1.50	1.50	#N/A	R2	**12**
-1.51	-1.51	#N/A		
-2.43	-2.43	#N/A		
2.74	2.74	#N/A		
1.37	1.37	#N/A		
1.47	1.47	#N/A		
4.74	4.74	#N/A		
2.93	2.93	#N/A		
3.05	3.05	#N/A		
1.92	1.92	#N/A		
1.99	1.99	#N/A		

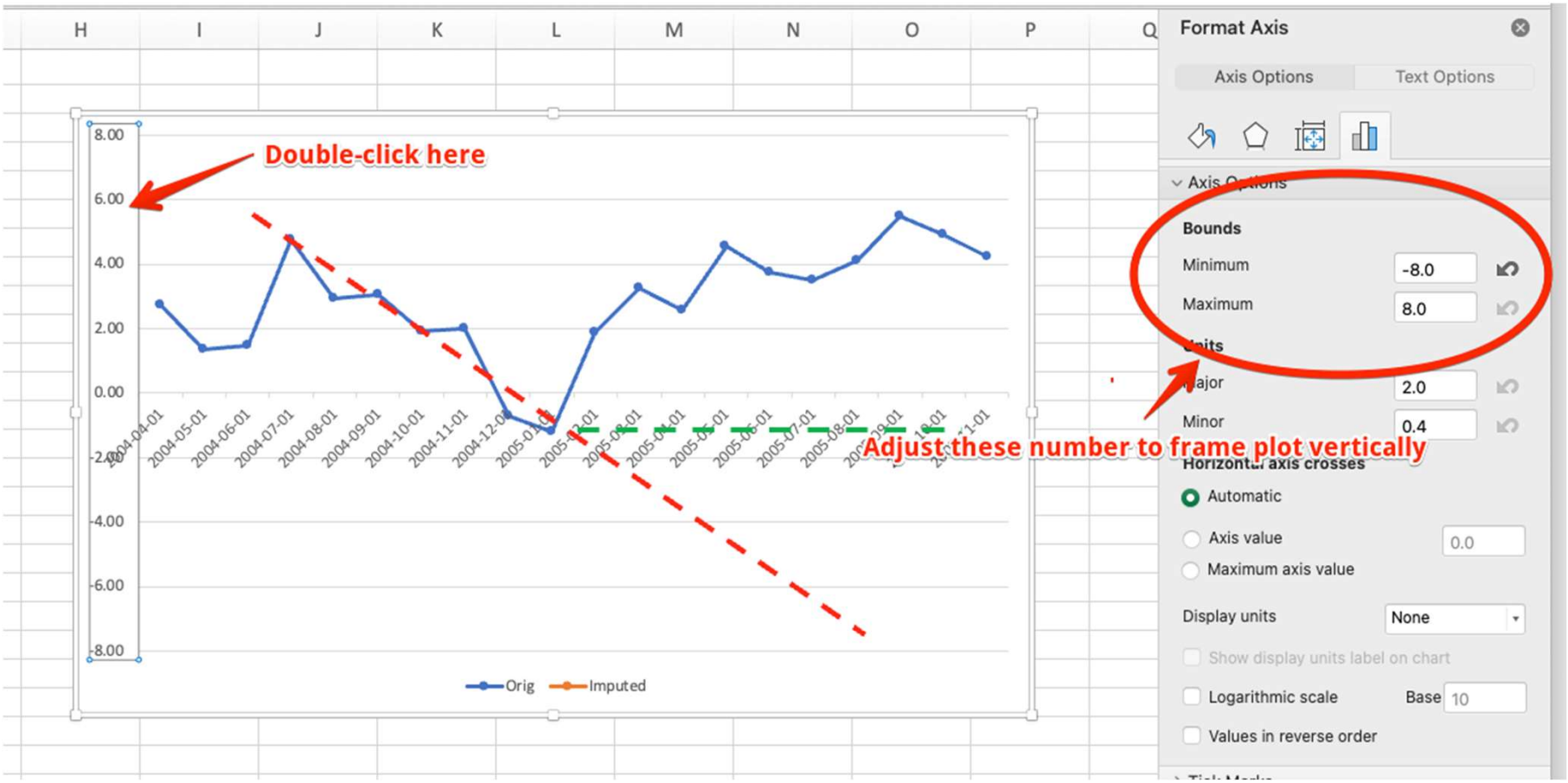




$R_1 = R_S$

$R_2 = R_S + R_D$

Framing vertical axis for line fitting



After processing each year, view final results

	A	B	C
1	**Recharge Rate Sumary**		
2			
3	**Year**	**R1**	**R2**
4	2002	5.6	10.5
5	2003	7.5	12
6	2004	6	11
7	2005	3.3	7.5
8	2006	3.2	6
9	2007	2.7	5
10	2008	4.4	7.6
11	2009	3	6
12	2010	3.8	9.2
13	2011	3.8	8
14	2012	4.6	9.6
15	2013	3.2	6
16	2014	7	13
17	2015	7	13
18	2016	4.3	10
19	2017	4	8
20	2018	3	6.3
21	2019	4	8
22	2020	3.5	7
23			
24	**Mean**	**4.4**	**8.6**
25