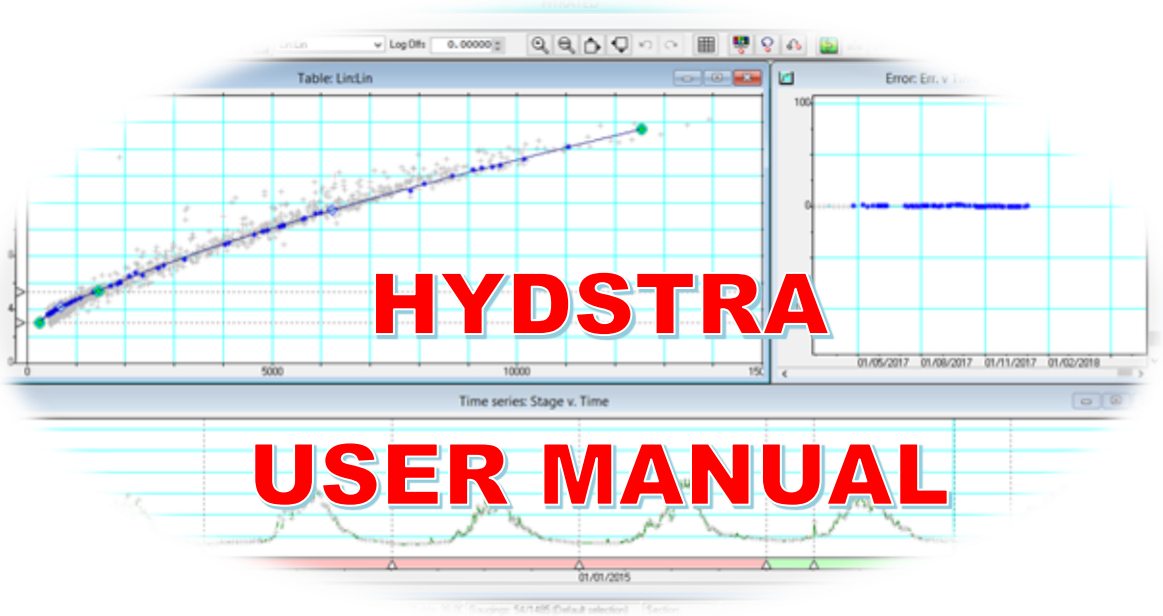
PAKISTAN

WATER AND DEVELOPMENT AUTHORITY

DFAT-CSIRO Indus Sustainable Development Investment Portfolio (SDIP)-Australia



FOR ANALYSIS OF CLIMATE DATA

SWHP-WAPDA

April 2019

CSIRO

Australian Aid

KISTERS

CONTRIBUTOR

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KISTERS

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Some important Codes used in Hydstra

400.00	Dry Bulb Temperature [degree Celsius]
410.00	Wet Bulb Temperature [degree Celsius]
420.00	Dew Point [degree Celsius]
430.00	Humidity [percentage]
460.00	Maximum Air Temperature [degree Celsius]
470.00	Maximum Air Temperature [degree Celsius]
520.00	Wind Run [kilometres]
700.00	Evaporation [millimetres]
151	Missing data for gauge

1. Introduction

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and, its subcontractor, KISTERS, of Australia have been supporting SWHP-WAPDA through the capacity building of the staff in the implementation of the HYDSTRA software since 2016 to improve time series hydrological and climate data processing and management.

The CSIRO of Australia, is helping Pakistan to build modern water management and assessment tools for the Indus Basin (https://research.csiro.au/sdip/projects/indus/) under Sustainable Development Investment Portfolio (SDIP) of Australian Government. This work was undertaken in the context of a Subsidiary Arrangement (established in 2016) and a Memorandum of Understanding (established in 2018) between the Government of Australia and the Government of Pakistan (http://mowr.gov.pk/index.php/press-release/).

Because the software has capability to process, archive and distribution of flow, climate, water quality and groundwater data sets (http://kisters.com.au/hydstra.html). Therefore, Software was modified to analyse and reporting the discharge and climate data according to the requirement of SWHP WAPDA. The computed climate data were also compared with the manual calculations (the procedure already being used in SWHP-WAPDA). HYDSTRA reproduced the same results for the Tarbela Dam climate stations when compared with the manual calculations.

Mr. Arif Shah, climate data analyst at SWHP-WAPDA got training sessions at SWHP office to use hydstra for climate data processing. Software, may be helpful for Research Directorate (H&R) because they also analyse the climate data manually.

The purpose of this manual is to provide the users sufficient details about the procedures to carry out climate data processing using HYDSTRA.

2. Existing methodology used for analysis of climate data and its reporting at SWHP-WAPDA

a) Precipitation (inches), evaporation (inches), anemo meter reading (Miles), Max., min, dry and Wet temperatures (Degree F) are measured at the site and recorded in the following Performa (Figure 1): Dry and wet bulb temperatures are observed at 8:00 am and 5:00 pm, whereas, all other data is measured at 8:00 am.

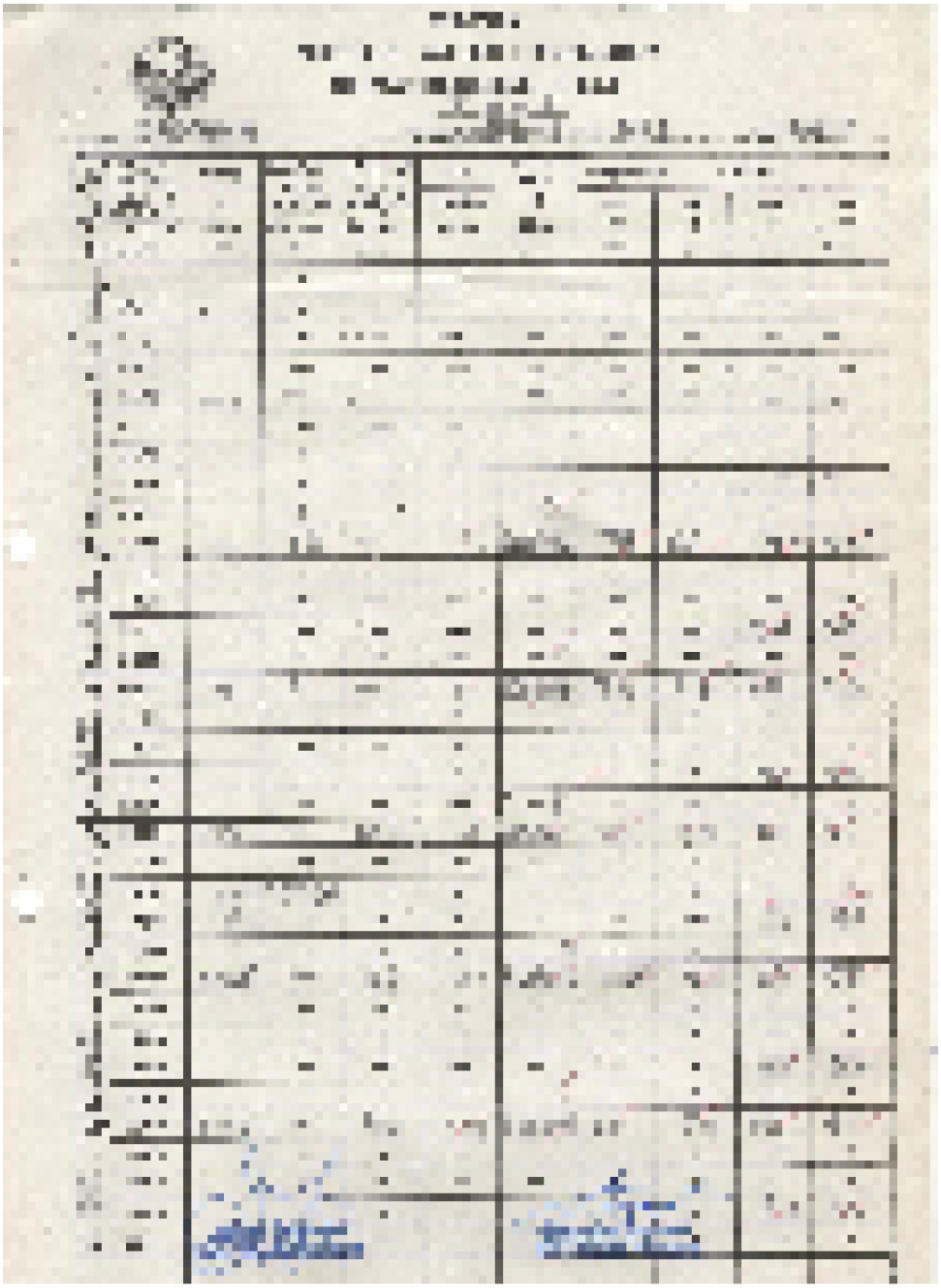


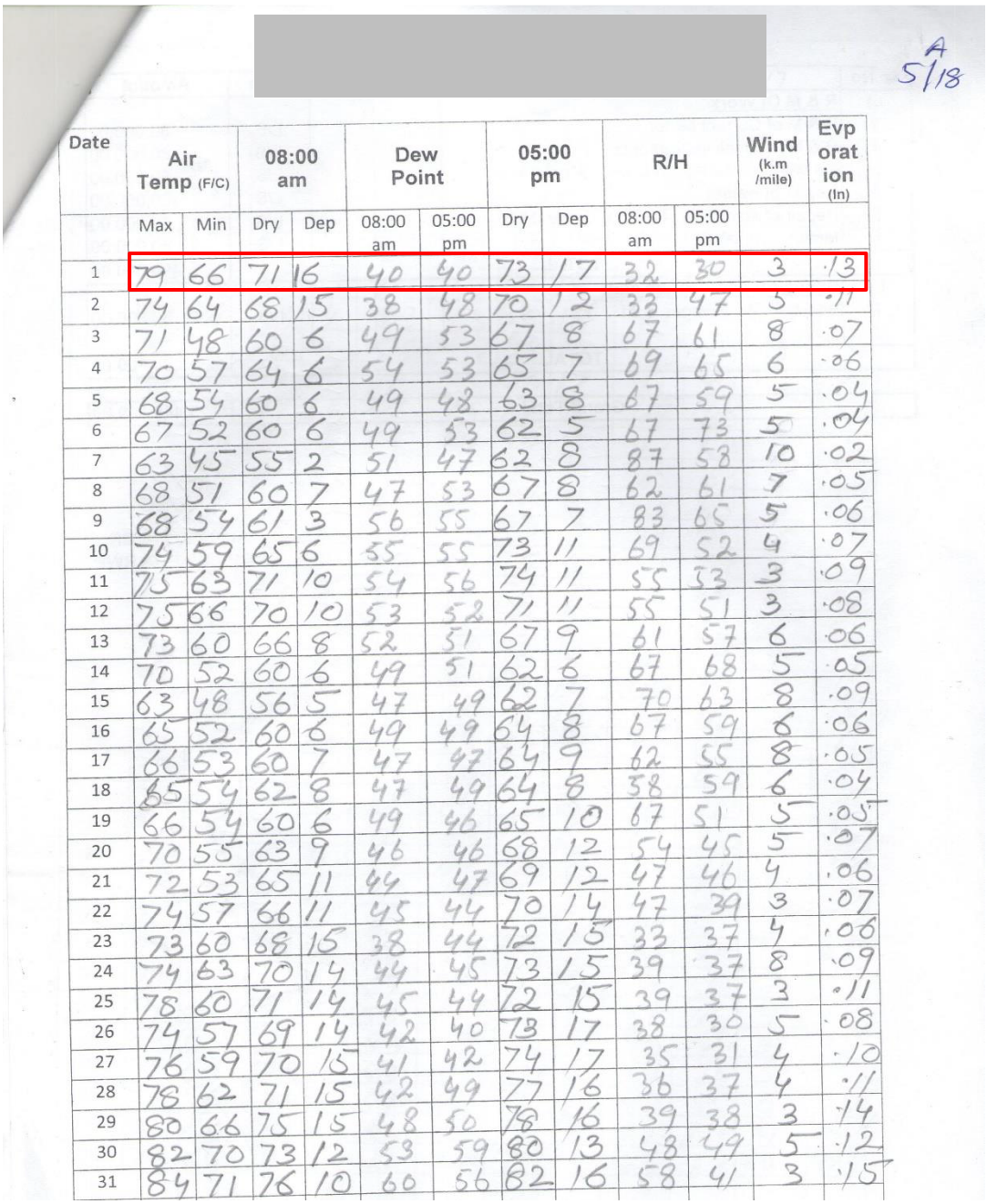
Figure 1: Proforma for recording daily climatological data

b) Then the other proforma is used to record the daily values as shown in Figure 2. Max., min. and dry Air temperatures are written as it is. Whereas, the fourth column

with heading 'Dep' contains the difference of Dry and Wet bulb temperatures. Same procedure is done for column '5:00 pm'.

c) The values of Dry and Dep in columns 8:00 am and 5:00 pm are used to calculate the Dew point and Relative Humidity from the tables (Figure 3). There are about 40 pages of R.H and Dew point readings. Wind is calculated by subtracting the value of previous day.

d) Data entry and final report printing is done using Excel sheets as shown in figure 4.



A
5/18

Date	Air Temp (F/C)		08:00 am		Dew Point		05:00 pm		R/H		Wind (k.m /mile)	Evp orat ion (In)
	Max	Min	Dry	Dep	08:00 am	05:00 pm	Dry	Dep	08:00 am	05:00 pm		
1	79	66	71	16	40	40	73	17	32	30	3	.13
2	74	64	68	15	38	48	70	12	33	47	5	.11
3	71	48	60	6	49	53	67	8	67	61	8	.07
4	70	57	64	6	54	53	65	7	69	65	6	.06
5	68	54	60	6	49	48	63	8	67	59	5	.04
6	67	52	60	6	49	53	62	5	67	73	5	.04
7	63	45	55	2	51	47	62	8	87	58	10	.02
8	68	51	60	7	47	53	67	8	62	61	7	.05
9	68	54	61	3	56	55	67	7	83	65	5	.06
10	74	59	65	6	55	55	73	11	69	52	4	.07
11	75	63	71	10	54	56	74	11	55	53	3	.09
12	75	66	70	10	53	52	71	11	55	51	3	.08
13	73	60	66	8	52	51	67	9	61	57	6	.06
14	70	52	60	6	49	51	62	6	67	68	5	.05
15	63	48	56	5	47	49	62	7	70	63	8	.09
16	65	52	60	6	49	49	64	8	67	59	6	.06
17	66	53	60	7	47	47	64	9	62	55	8	.05
18	65	54	62	8	47	49	64	8	58	59	6	.04
19	66	54	60	6	49	46	65	10	67	51	5	.05
20	70	55	63	9	46	46	68	12	54	45	5	.07
21	72	53	65	11	44	47	69	12	47	46	4	.06
22	74	57	66	11	45	44	70	14	47	39	3	.07
23	73	60	68	15	38	44	72	15	33	37	4	.06
24	74	63	70	14	44	45	73	15	39	37	8	.09
25	78	60	71	14	45	44	72	15	39	37	3	.11
26	74	57	69	14	42	40	73	17	38	30	5	.08
27	76	59	70	15	41	42	74	17	35	31	4	.10
28	78	62	71	15	42	49	77	16	36	37	4	.11
29	80	66	75	15	48	50	78	16	39	38	3	.14
30	82	70	73	12	53	59	80	13	48	49	5	.12
31	84	71	76	10	60	56	82	16	58	41	3	.15

Figure 2: Manual calculations of Dew point, Relative humidity and wind in last 24 hrs.

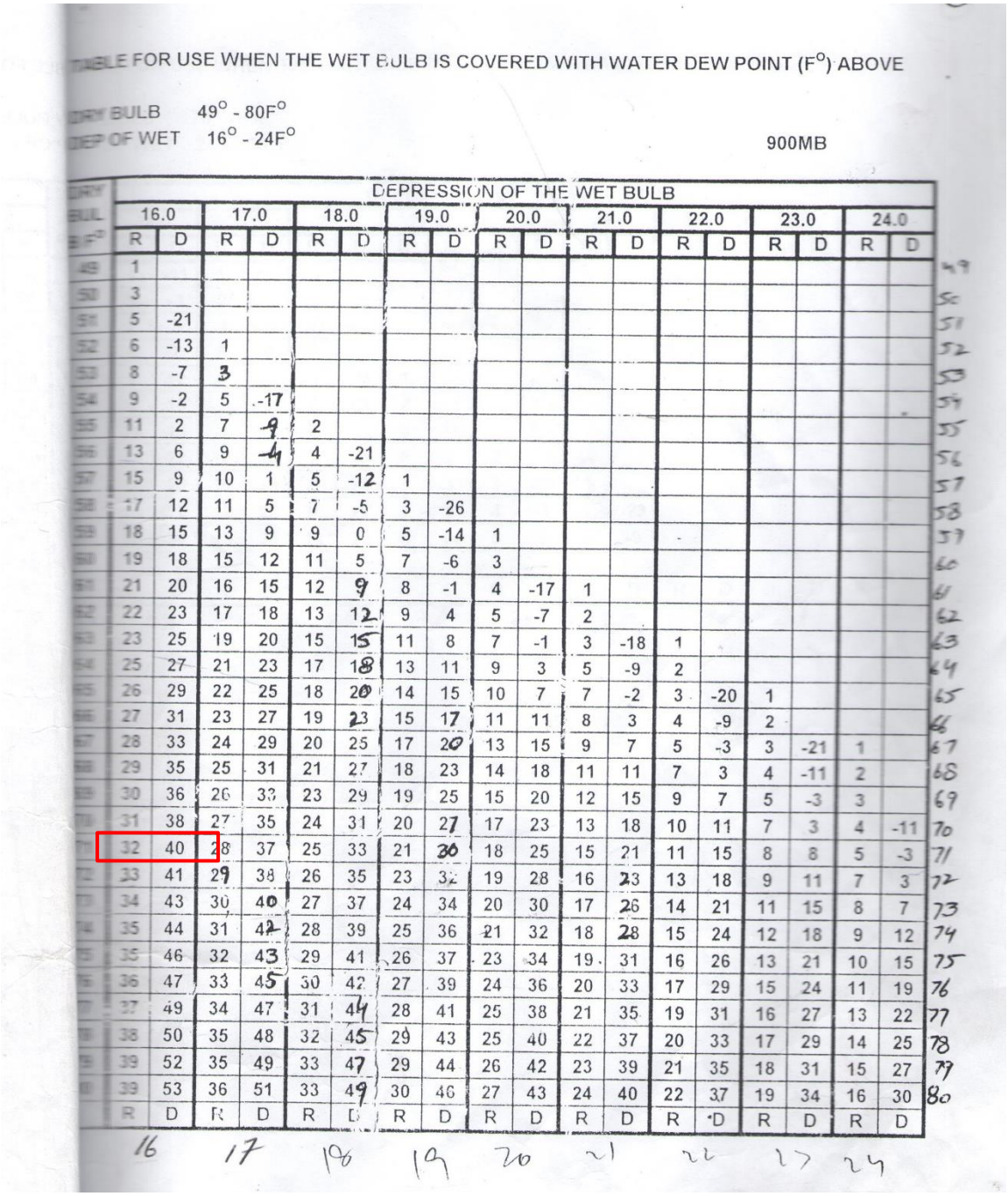


TABLE FOR USE WHEN THE WET BULB IS COVERED WITH WATER DEW POINT (F°) ABOVE

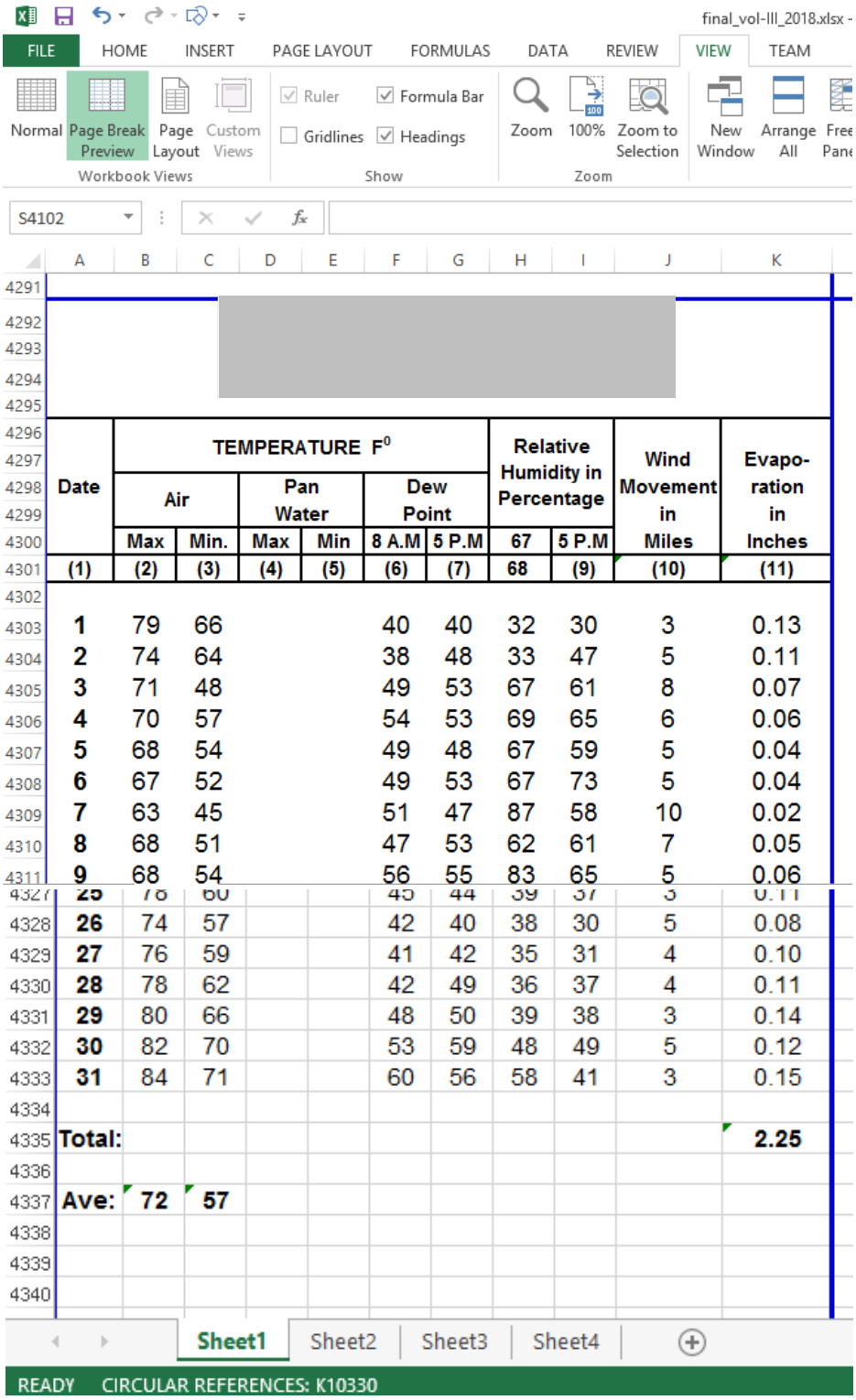
DRY BULB 49° - 80F°
DEP OF WET 16° - 24F°

900MB

DRY BULB °F	DEPRESSION OF THE WET BULB																	
	16.0		17.0		18.0		19.0		20.0		21.0		22.0		23.0		24.0	
	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
49	1																	
50	3																	
51	5	-21																
52	6	-13	1															
53	8	-7	3															
54	9	-2	5	-17														
55	11	2	7	-9	2													
56	13	6	9	-4	4	-21												
57	15	9	10	1	5	-12	1											
58	17	12	11	5	7	-5	3	-26										
59	18	15	13	9	9	0	5	-14	1									
60	19	18	15	12	11	5	7	-6	3									
61	21	20	16	15	12	9	8	-1	4	-17	1							
62	22	23	17	18	13	12	9	4	5	-7	2							
63	23	25	19	20	15	15	11	8	7	-1	3	-18	1					
64	25	27	21	23	17	18	13	11	9	3	5	-9	2					
65	26	29	22	25	18	20	14	15	10	7	7	-2	3	-20	1			
66	27	31	23	27	19	23	15	17	11	11	8	3	4	-9	2			
67	28	33	24	29	20	25	17	20	13	15	9	7	5	-3	3	-21	1	
68	29	35	25	31	21	27	18	23	14	18	11	11	7	3	4	-11	2	
69	30	36	26	33	23	29	19	25	15	20	12	15	9	7	5	-3	3	
70	31	38	27	35	24	31	20	27	17	23	13	18	10	11	7	3	4	-11
71	32	40	28	37	25	33	21	30	18	25	15	21	11	15	8	8	5	-3
72	33	41	29	38	26	35	23	32	19	28	16	23	13	18	9	11	7	3
73	34	43	30	40	27	37	24	34	20	30	17	26	14	21	11	15	8	7
74	35	44	31	42	28	39	25	36	21	32	18	28	15	24	12	18	9	12
75	35	46	32	43	29	41	26	37	23	34	19	31	16	26	13	21	10	15
76	36	47	33	45	30	42	27	39	24	36	20	33	17	29	15	24	11	19
77	37	49	34	47	31	44	28	41	25	38	21	35	19	31	16	27	13	22
78	38	50	35	48	32	45	29	43	25	40	22	37	20	33	17	29	14	25
79	39	52	35	49	33	47	29	44	26	42	23	39	21	35	18	31	15	27
80	39	53	36	51	33	49	30	46	27	43	24	40	22	37	19	34	16	30
	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D

16 17 18 19 20 21 22 23 24

Figure 3: Table used to see the Dew point and Relative humidity values



Date	TEMPERATURE F⁰						Relative Humidity in Percentage		Wind Movement in Miles	Evapo-ration in Inches
	Air		Pan Water		Dew Point					
	Max	Min.	Max	Min	8 A.M	5 P.M	67	5 P.M		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	68	(9)	(10)	(11)
1	79	66			40	40	32	30	3	0.13
2	74	64			38	48	33	47	5	0.11
3	71	48			49	53	67	61	8	0.07
4	70	57			54	53	69	65	6	0.06
5	68	54			49	48	67	59	5	0.04
6	67	52			49	53	67	73	5	0.04
7	63	45			51	47	87	58	10	0.02
8	68	51			47	53	62	61	7	0.05
9	68	54			56	55	83	65	5	0.06
26	74	57			42	40	38	30	5	0.08
27	76	59			41	42	35	31	4	0.10
28	78	62			42	49	36	37	4	0.11
29	80	66			48	50	39	38	3	0.14
30	82	70			53	59	48	49	5	0.12
31	84	71			60	56	58	41	3	0.15
Total:										2.25
Ave:	72	57								

Figure 4: Print screen of final report.

3. Limitations of the above methodology used to calculate the R.H and Dew Point Temperature manually

Tables used to calculate R.H and D.P temperature are based on two pressure values only i.e., 900 mb and 1000 mb. Therefore, the calculations of R.H and D.P temperature are based on these two pressure values. Whereas, the pressure of the stations varies from 682 mb to 1010 mb for the SWHP climate sites (Annex. 1).

4. Methodology used to calculate R.H and D.P Temperature in Hydstra

a) Calculation of Pressure

Saturation vapour pressure at wet bulb dew point temperature and relative humidity requires the calculation of air pressure at meteorological stations. Moreover, pressure is a function of weather station height w.r.t sea level.

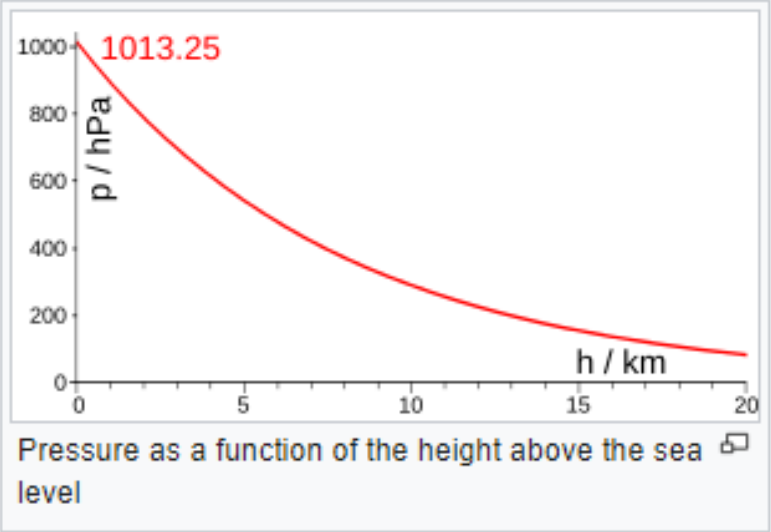


Figure 5: Relationship between pressure and elevation

Therefore, first pressure is calculated. Following formula is used to calculate the pressure at the weather station:

$$P = P_b \cdot \left[\frac{T_b}{T_b + L_b \cdot (h - h_b)} \right]^{\frac{g_0 \cdot M}{R^* \cdot L_b}}$$

P_b, Static pressure = 1013.25 Pa or mb

T_b, standard temperature = 273.16 K

L_b, standard temperature lapse rate = -0.0065 K/m

h, height above sea level in meters

h_b, height at bottom of layer b = 0 m

R*, universal gas constant = 8.3144589 J/mol/K

g_0, gravitational acceleration = 9.80665 m/s^2

M, molar mass of Earth's air = 0.028964 kg/mol

Calculated pressures for each site are given in Annexure 1.

b) Relative Humidity Calculation

Sprung Formula is used to calculate the relative humidity

$$RH = 100 \cdot \frac{e_s(t_w) - A \cdot p \cdot (t_d - t_w)}{e_s(t_d)}$$

$e_s(t_w)$ is the saturation vapour pressure of the wet bulb;
$e_s(t_d)$ is the saturation vapour pressure of the dry bulb;
p is the pressure of the air;
t_d is the temperature of the dry bulb;
t_w is the temperature of the wet bulb;
A is the psychrometer coefficient A = 0.0008, used by PMD as mentioned in their booklets

Saturated vapour pressures at dry and wet bulb temperatures are used to calculate using Magnus Formula which is adopted by WMO

$$6.112 * e^{\frac{17.62*tw}{243.12+tw}}$$

$$6.112 * e^{\frac{17.62*td}{243.12+td}}$$

es(tw) is saturation vapour pressure at wet bulb temperature

es(td) is saturation vapour pressure of air at dry bulb Temp.

c) Dew point is calculated using the following formula

$$\frac{243.12 * \ln(\frac{e_{(d)}}{6.112})}{17.62 - \ln(\frac{e_{(d)}}{6.112})}$$

e_d is saturation vapour pressure at wet dew point

5. Steps in Hydstra

a) Climate data entry sheet

- **Open** the excel file of climate data entry placed at the following location:

E:\Climate data entry

Note: Ensure the path given in the validation sheet is correct. The box of Read only should be uncheck before correcting the path.

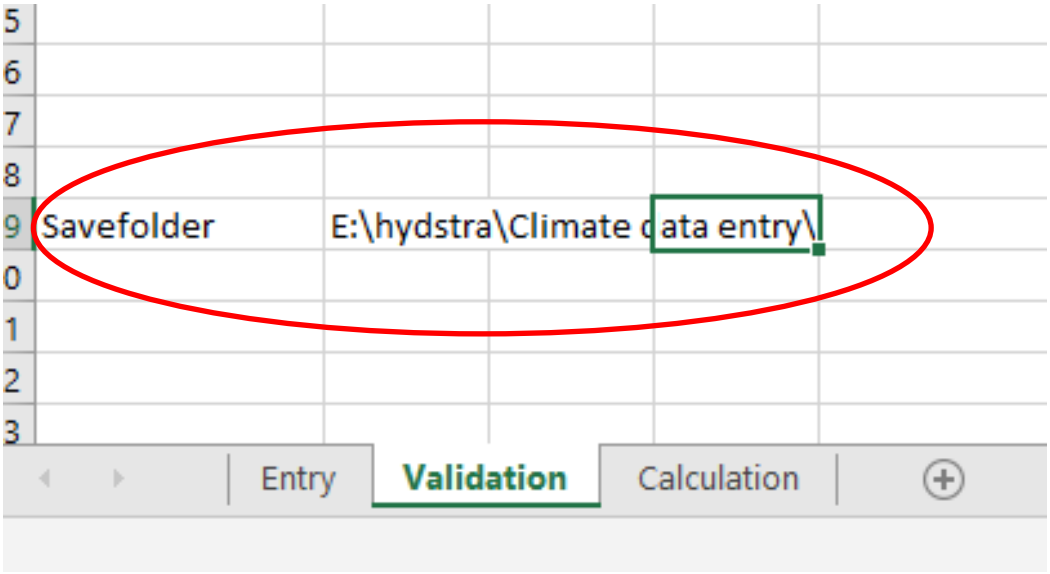


Figure 6: Editing path option for the climate data entry sheet

Although data can be directly entered in the sheet already available in the folder. However, the template can also be used to create a new sheet for the data manually in it and then import the file into hydstra.

- Double Click on the following option available in Hydstra to open the climate data entry template
  Company Favourities/ By Function/ Importing/ Open Climate Data Template

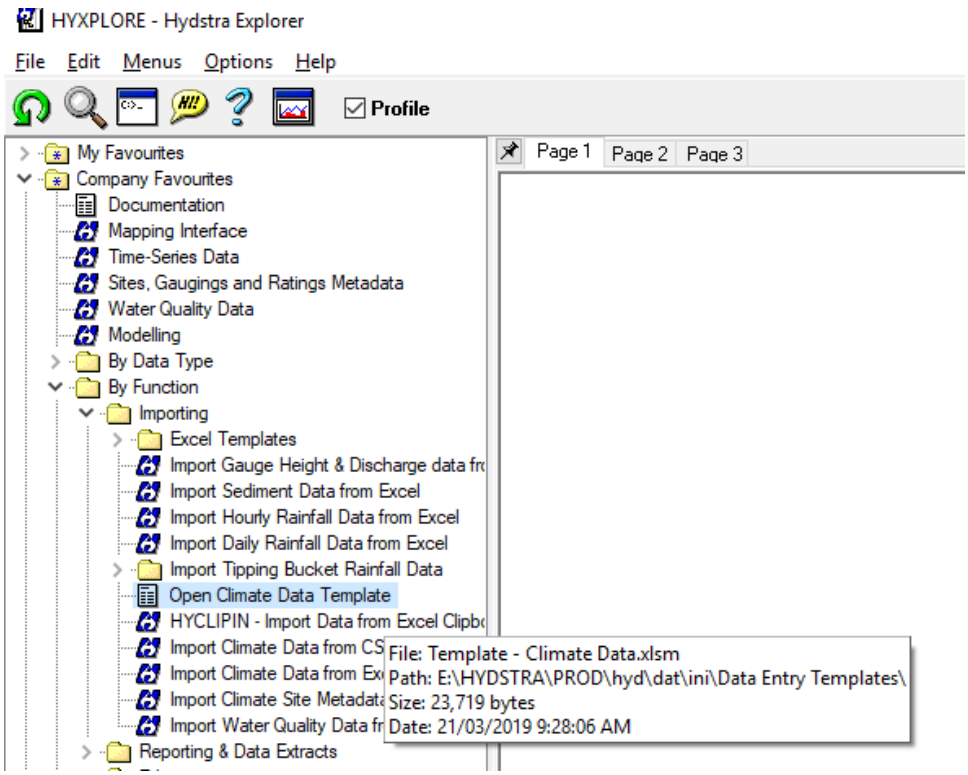


Figure 7: Path to open the climate data entry template

Enter the following information in the sheet

- Enter the station's information like Site code, data source, year, month and the units of parameters.
- Enter the climate data in the sheet i.e, Max, Minimum air temperatures, Dry and Wet Bulb temperatures, wind speed and pan evaporation (Figure 8).

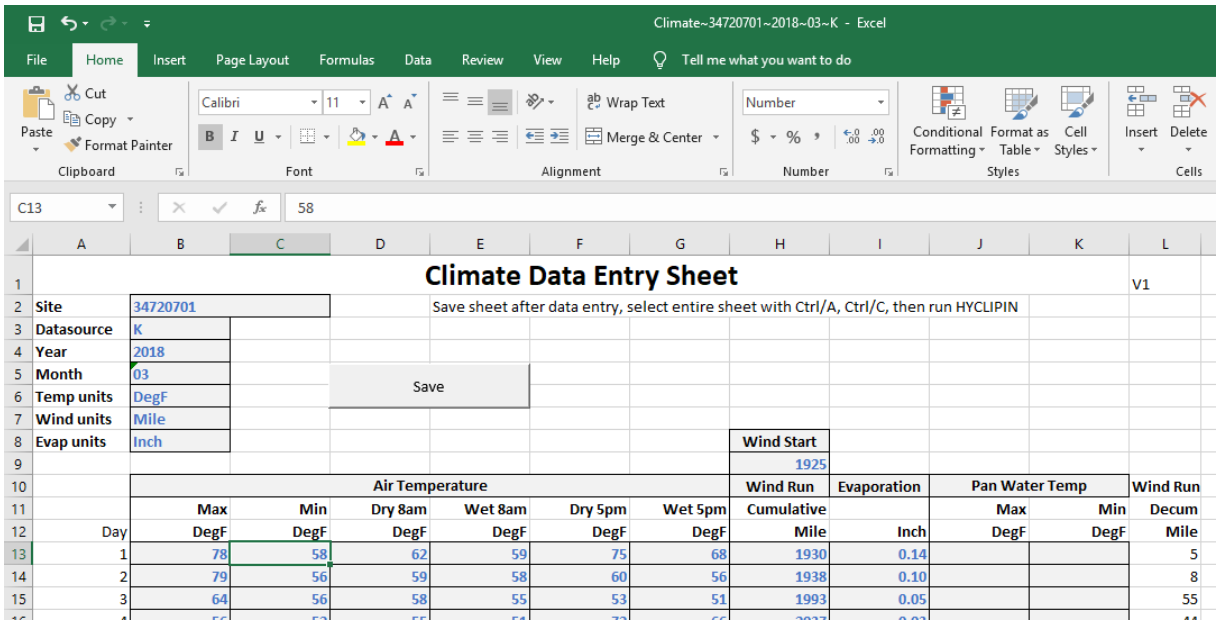
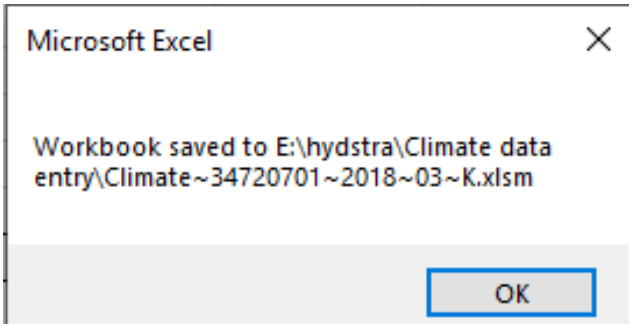


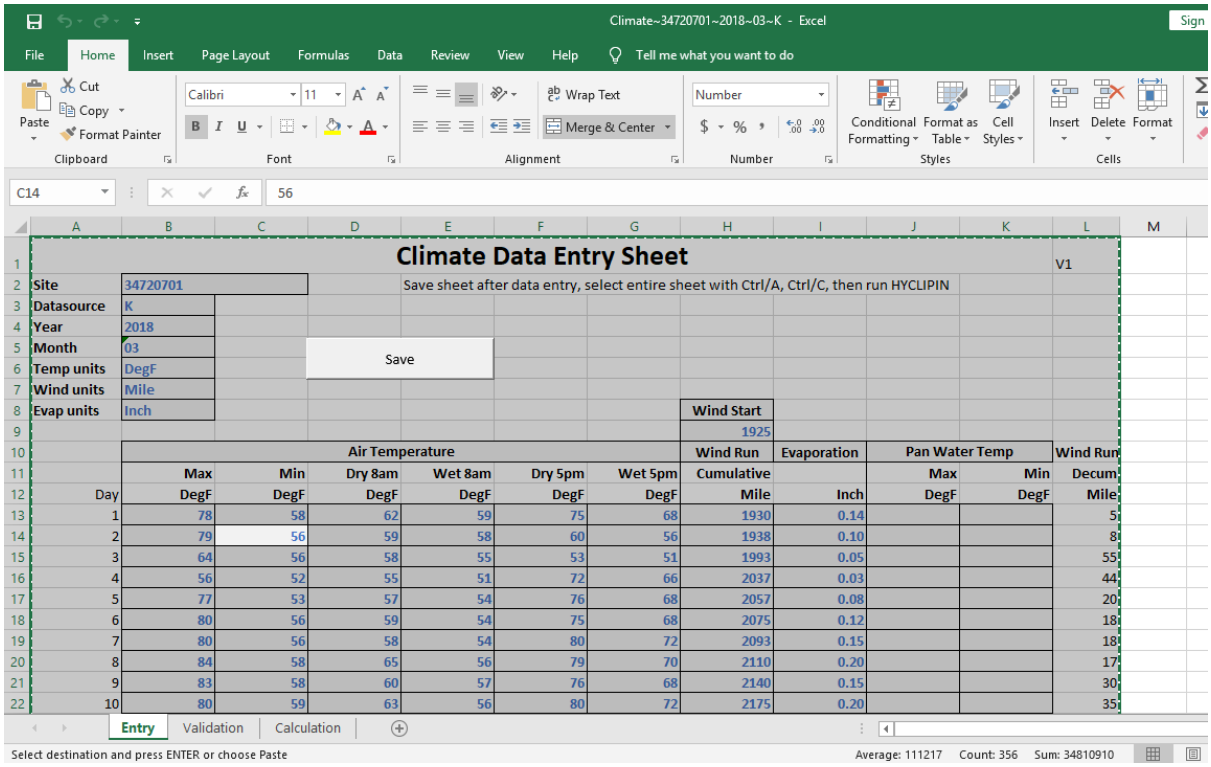
Figure 8: Climate data entry sheet

- **Save** the sheet by clicking the Save button and click ***OK***. A message will be shown that the workbook is saved at the given location. The file shows the station, year, month and code.

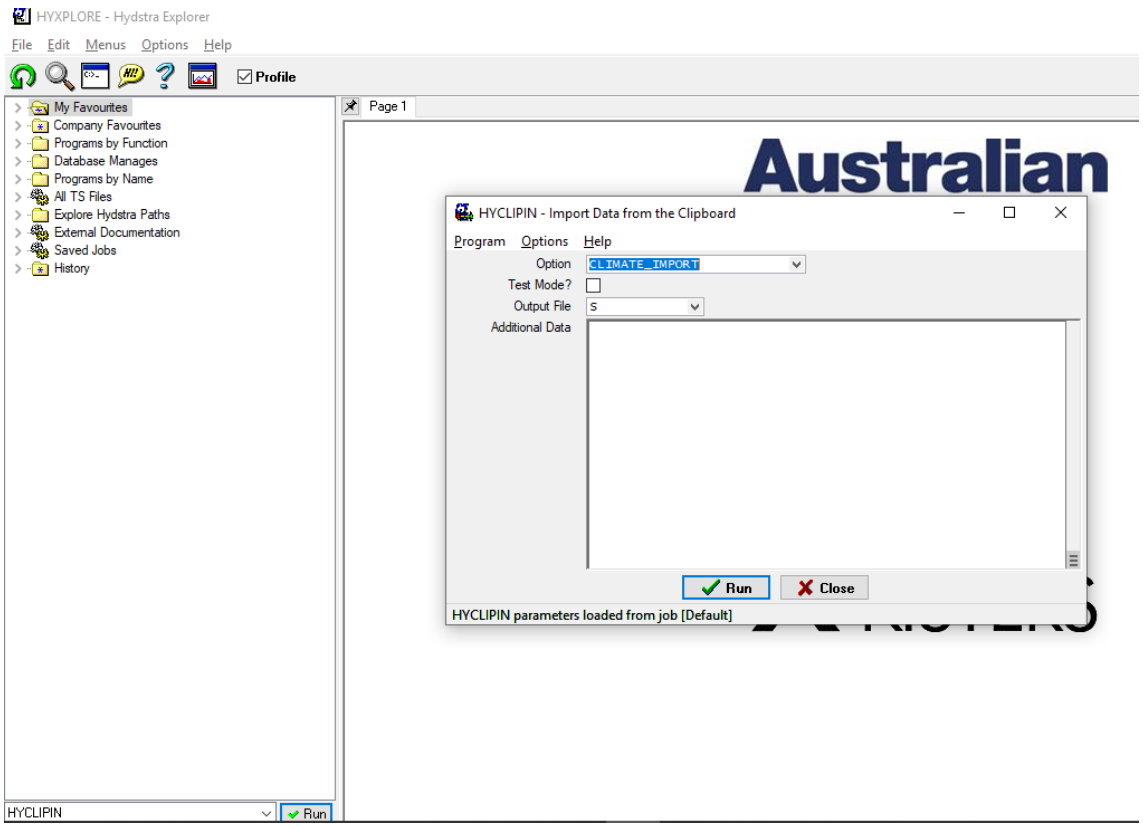


Note: after successful save, the path with site ID, Year, month and data source is written in the message box

- **Select** entire sheet with Cltr A. **Copy** the entire sheet with Cltr C.



- **Open** the Hydstra Explorer
- **Run** the hyclipin (A window of HYCLIPIN will be open)
- Click the **Run** button to import the data into hydstra.



Two sheets will be created in hydstra; first will show the information/data imported from the data entry file and the calculated values of R.H and D.P for each day and; the second sheet will show the graphs of each parameter (Figure ?).

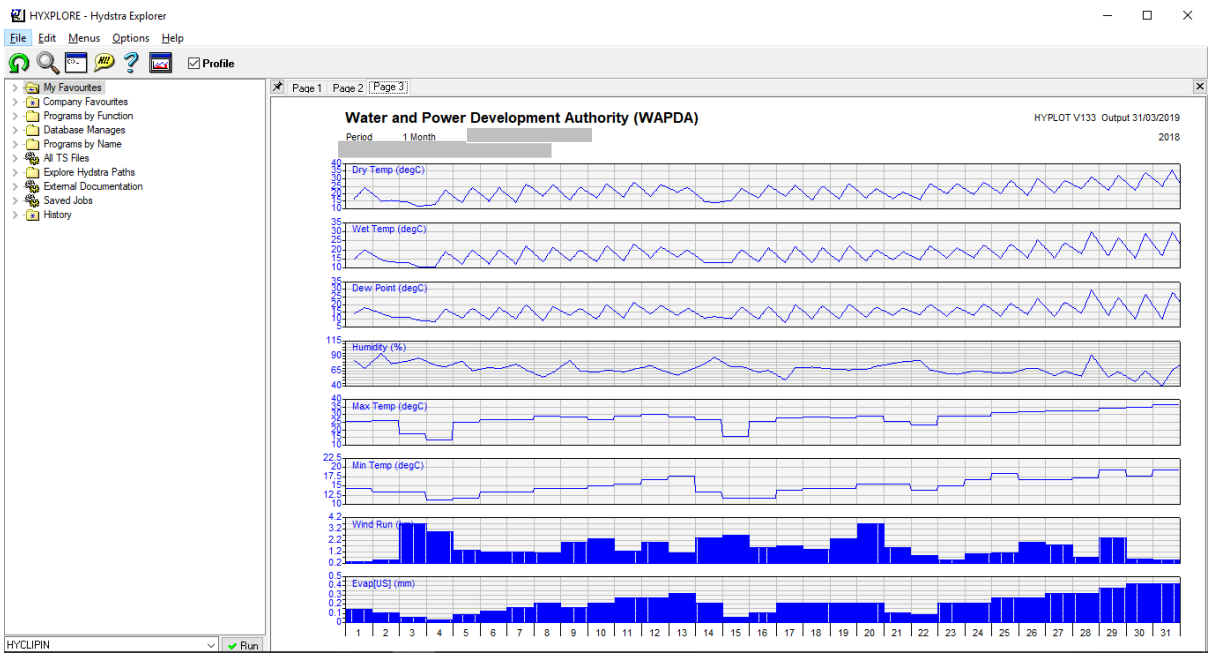


Figure 9: Graphical sheet appears automatically after successful import and calculations in hydstra

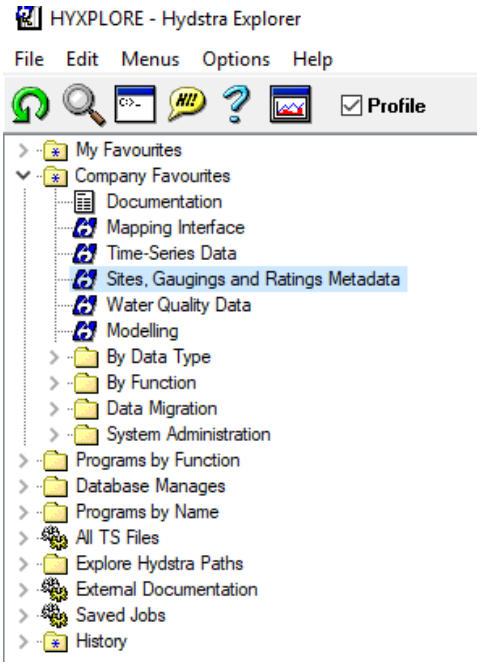
Note: If any wrong entry is added then edit the data entry sheet, save it and repeat the above procedure.

b) Creating/ Updating the information for Header Page of Climate Report

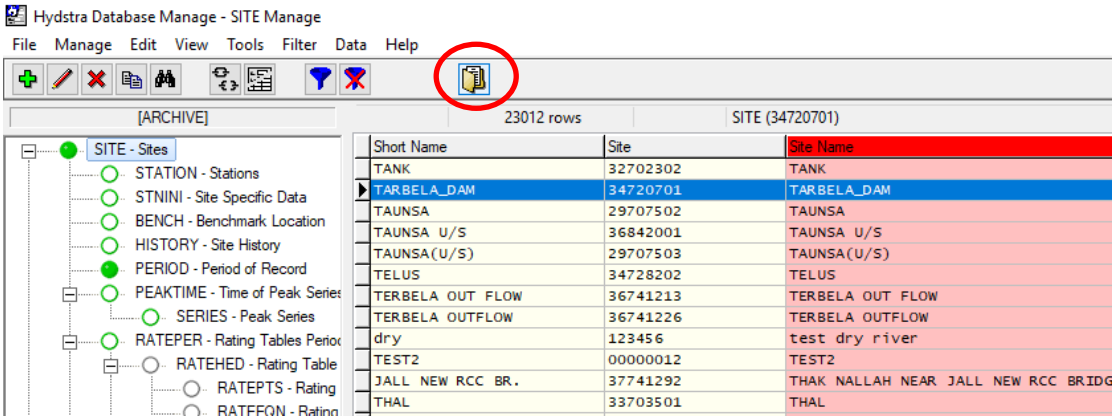
The sample for header sheet is placed at the location

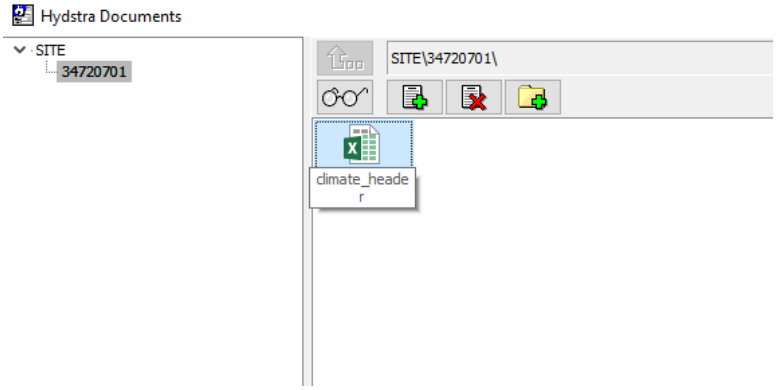
hyd\dat\site\

- **copy** it and **rename** as per site ID
- **Open** Hydstra and **double click** on 'Sites, Gauging and Ratings Metadata'

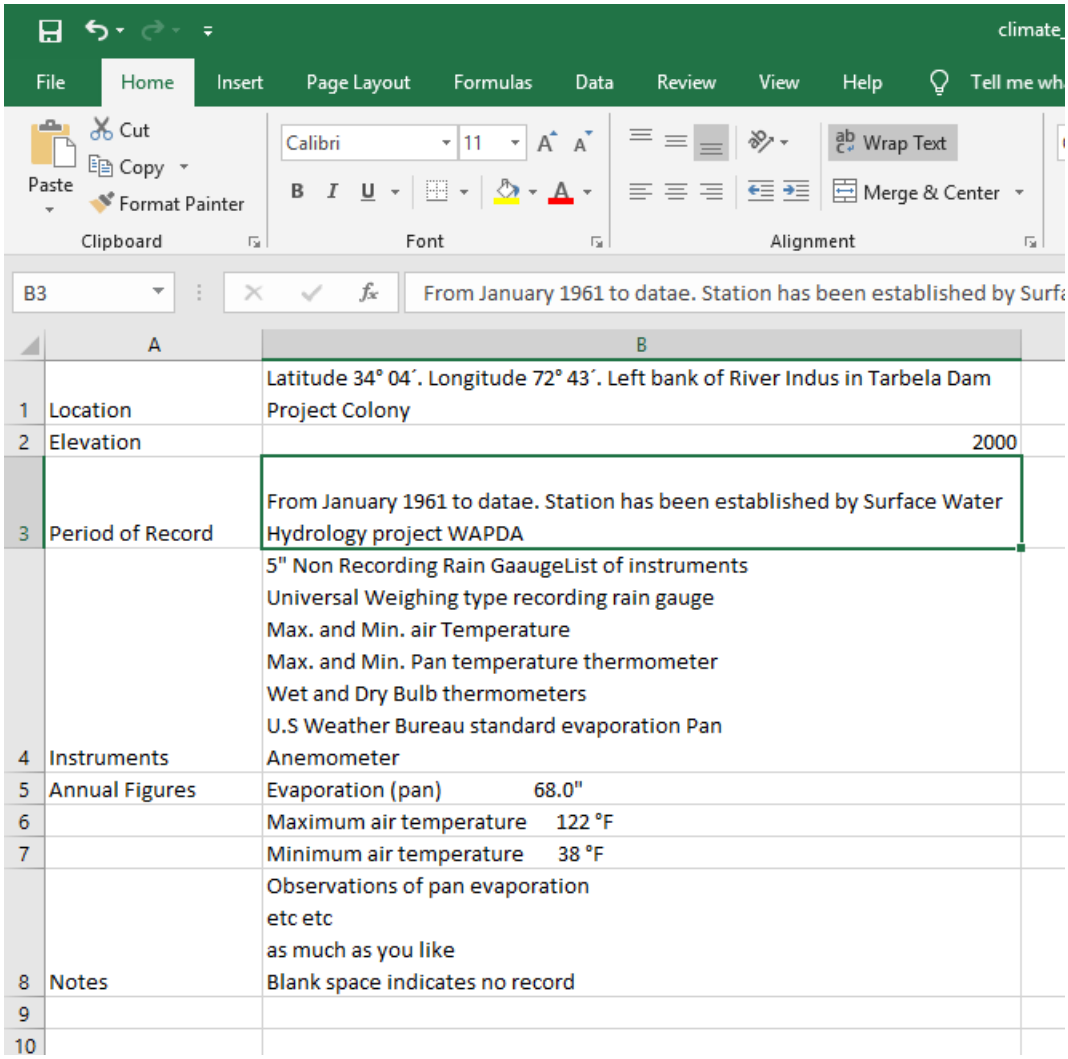


- **Select** the sites and **click** on the folder that shows the data exists for this record



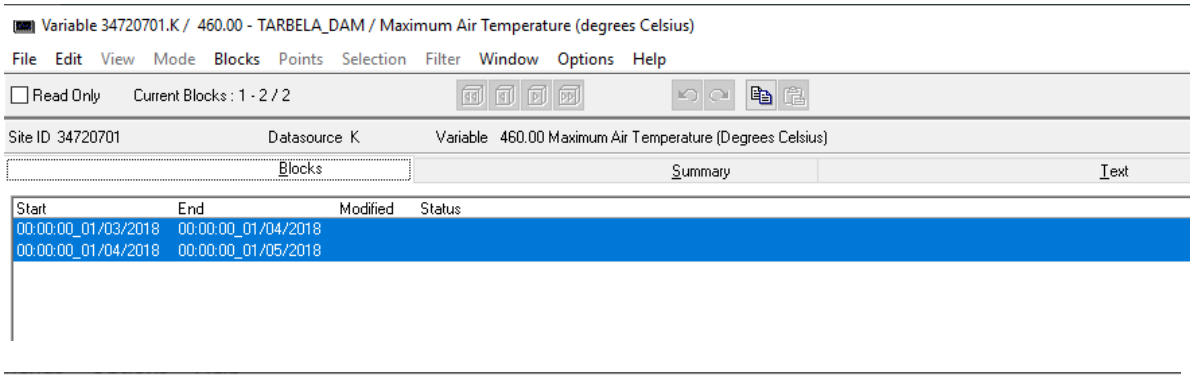


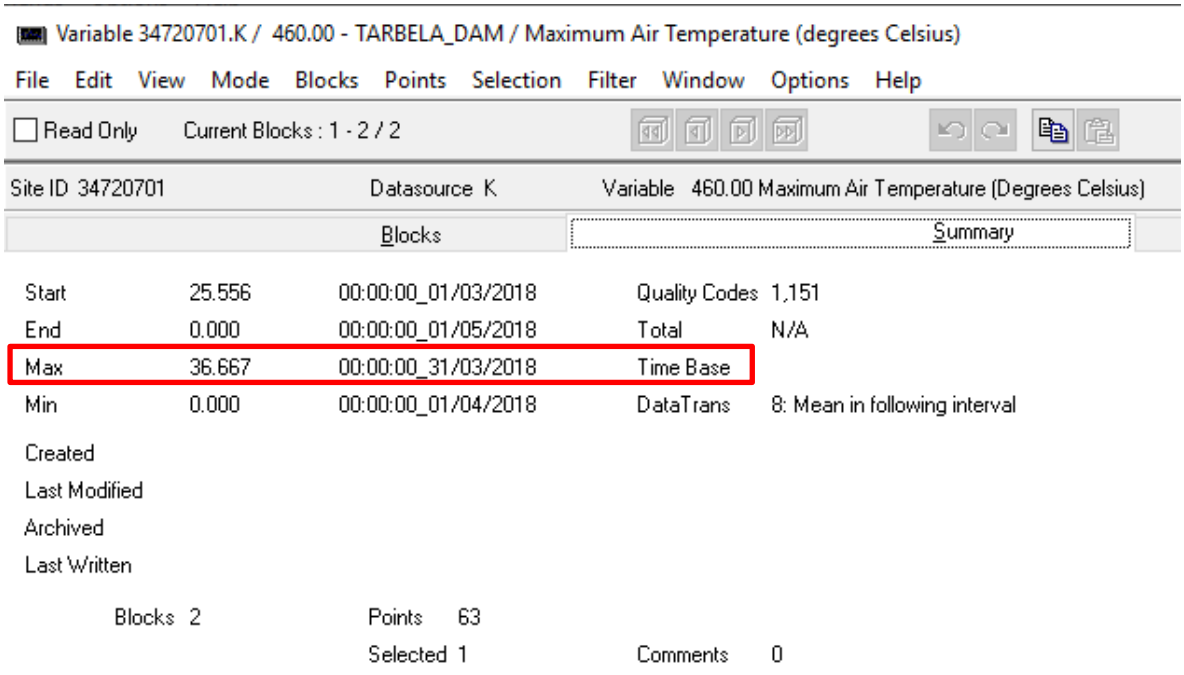
- **Open** the excel file by double clicking
- A file will be open that can be edited and updated. Annual figures can be taken from the time series file.
- After entering required information **save** the file.



	A	B
1	Location	Latitude 34° 04´. Longitude 72° 43´. Left bank of River Indus in Tarbela Dam Project Colony
2	Elevation	2000
3	Period of Record	From January 1961 to datae. Station has been established by Surface Water Hydrology project WAPDA
4	Instruments	5" Non Recording Rain GaaugeList of instruments Universal Weighing type recording rain gauge Max. and Min. air Temperature Max. and Min. Pan temperature thermometer Wet and Dry Bulb thermometers U.S Weather Bureau standard evaporation Pan Anemometer
5	Annual Figures	Evaporation (pan) 68.0"
6		Maximum air temperature 122 °F
7		Minimum air temperature 38 °F
8	Notes	Observations of pan evaporation etc etc as much as you like Blank space indicates no record
9		
10		

- **In time series, Open** the files of selected site
- **Select** the blocks and click the Summary tab





c) Generating climate Report for the year

Report of a selected station(s) can be generated in '.html' format using the following procedure.

- Double click on '*Report Climate data for a year*'

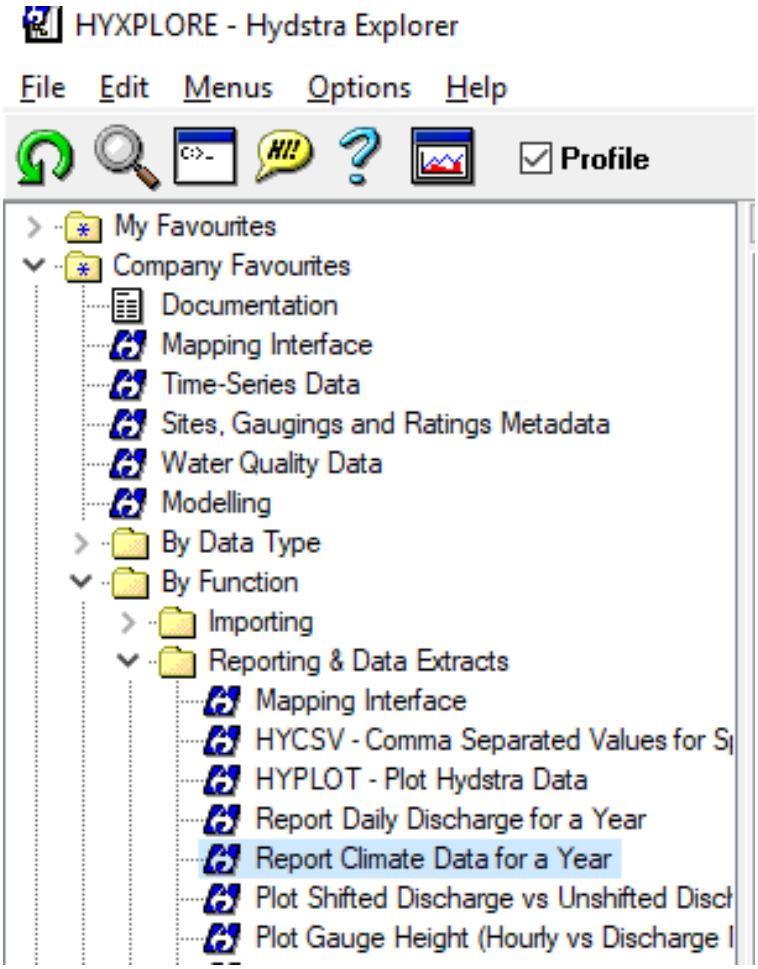


Figure 10: Option for creating climate report for a year in Hydstra

- **Select** the site and data source, year and other parameters
- **Write** the name of file at a selected path with extension .html. File will be saved in html format at the given path that can be inserted in Microsoft word, if required.

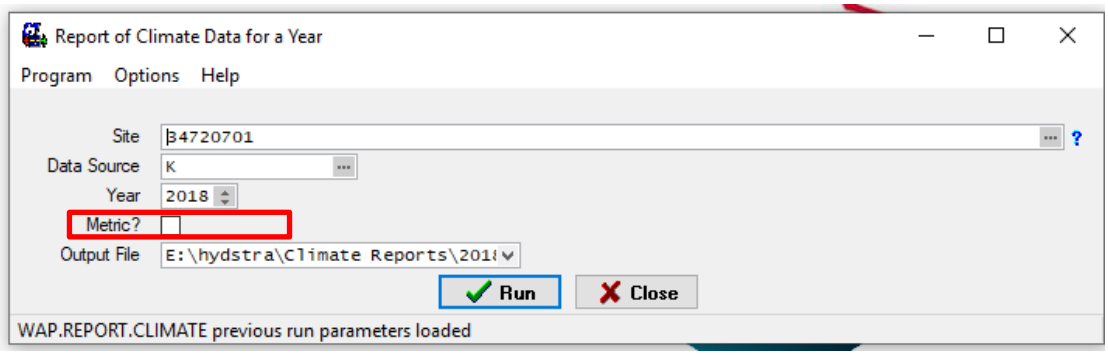


Figure 11: Creating report in html format

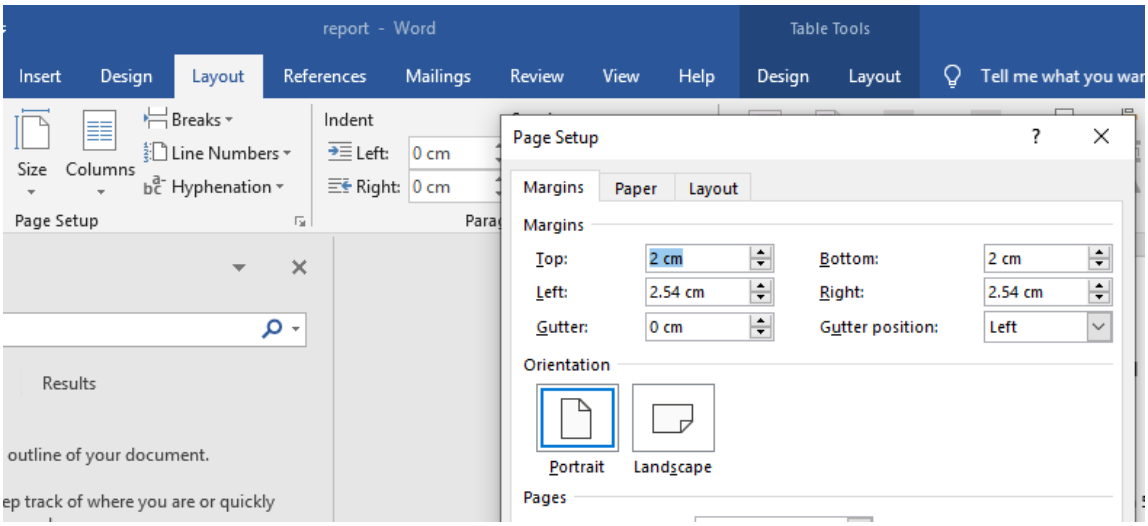
Note: If the yearly report is required in metric units then Check the box in front of Metric otherwise report will be generated in Imperial units.

Climate report of each station can be saved in a particular folder e.g., E:\Climate Reports\2018\Tarbela Dam.html

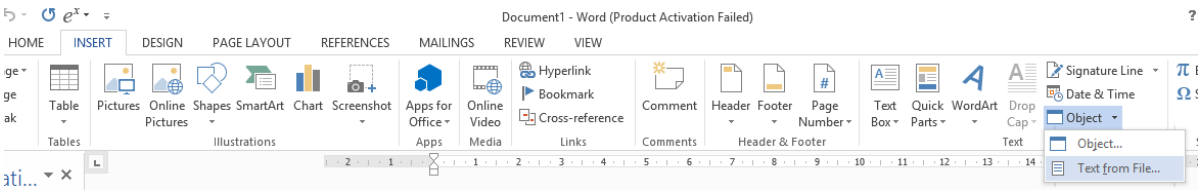
6. Creating Binder for all Climate sites (Volume 2 of SWHP Report)

When Climate data for all the stations are calculated and saved in .html format in the selected folder then all the files should be inserted in the word file.

- For this, **Open a new word file**. (Select the A4 Page size)
- Adjust margins as given below

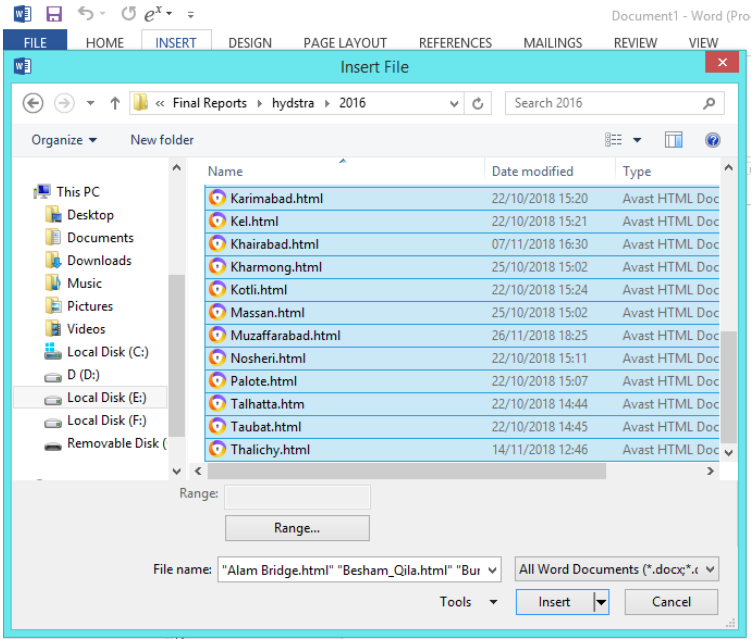


- Go to ***Insert tab*** of word file and click on ***Object*** and select ***Text from File***.

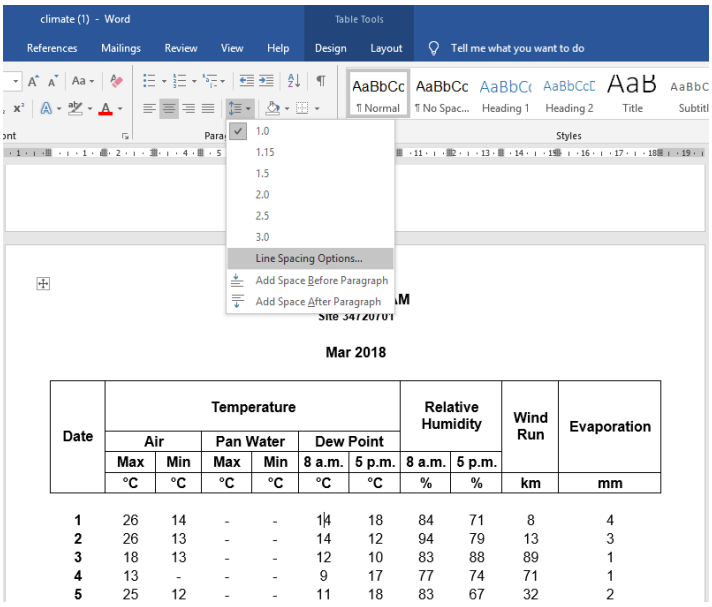


- Select all the .html files in the selected folder and click ***Insert*** button. All the files will be added in the new word file.

  Note: Files should be arranged in the same order as we required to be in printed form

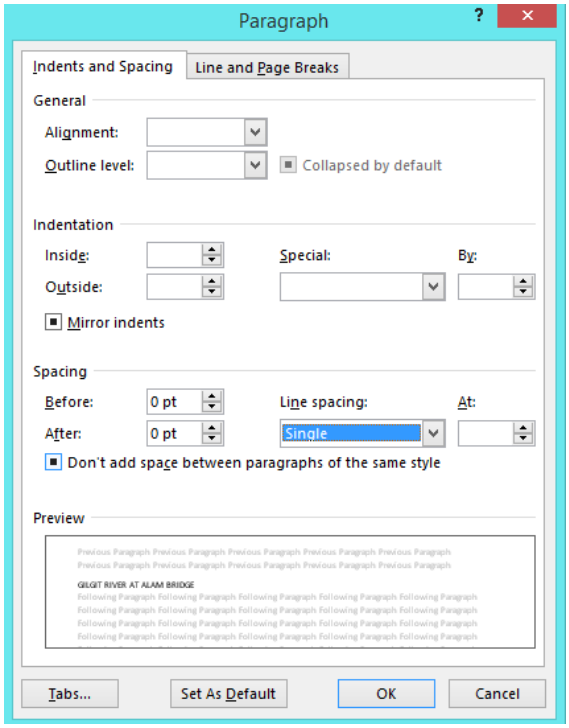


- Click on line spacing option under the Home tab



Date	Temperature						Relative Humidity		Wind Run	Evaporation
	Air		Pan Water		Dew Point					
	Max	Min	Max	Min	8 a.m.	5 p.m.	8 a.m.	5 p.m.		
	°C	°C	°C	°C	°C	°C	%	%	km	mm
1	26	14	-	-	14	18	84	71	8	4
2	26	13	-	-	14	12	94	79	13	3
3	18	13	-	-	12	10	83	88	89	1
4	13	-	-	-	9	17	77	74	71	1
5	25	12	-	-	11	18	83	67	32	2

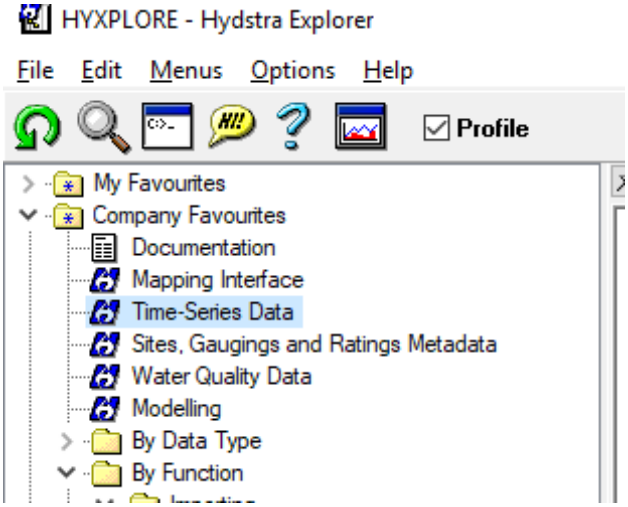
- Select the zero spacing and single line spacing as given in figure below.



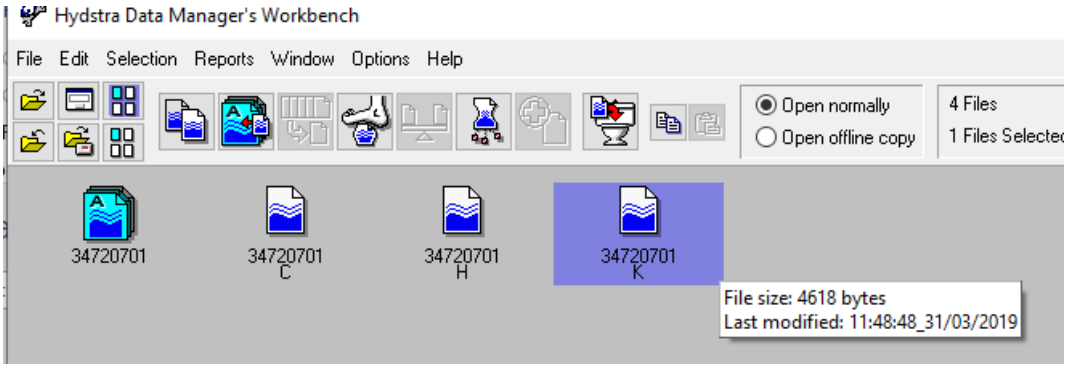
7. View Time Series Data in Hydstra

Climate data stores in a work file that can be access in hydstra by using the following procedure:

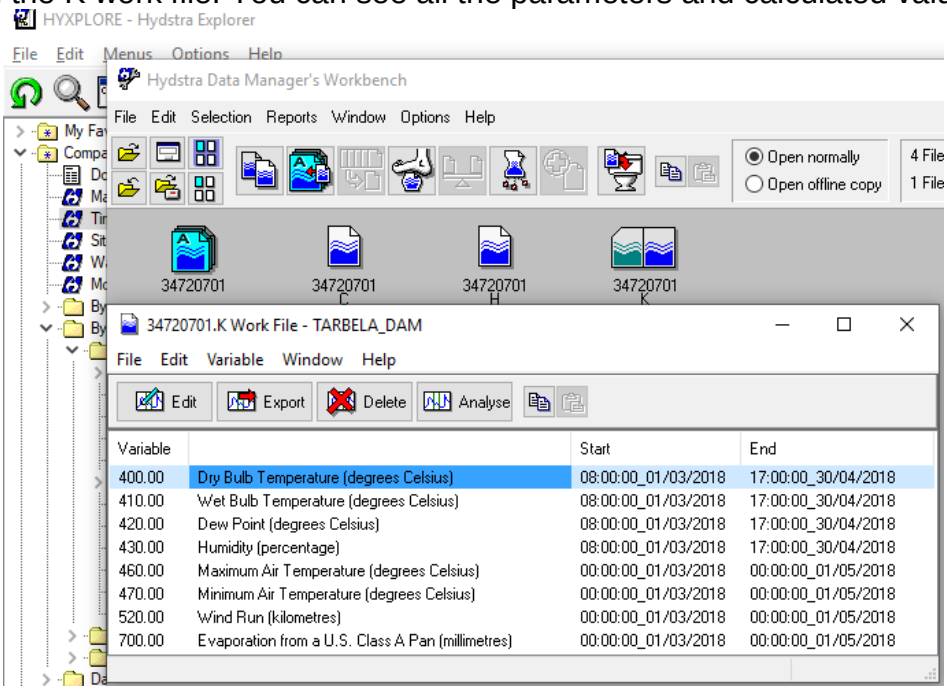
- **Double click** the Time-Series Data



- **Select** File and click on Open, a window will be shown
- **Enter** the site ID, all the files will be loaded



- **Open** the K work file. You can see all the parameters and calculated values



- Double click on the any parameter and see the graphical representation.

8. Some Additional Options in HYDSTRA

Please see the Manual of Discharge Data analysis for the following additional features and capabilities of Hydstra software:

- To add new site in a map window
- Copying time series data from one system to other system
- Changing the site ID
- Software Installation Guide

Annexure 1

Codes, Elevations and Pressure Calculations of SWHP Sites

Sites	Codes	Elevation (ft)	Elevation (m)	Pressure	
BAGH	33739701	3500	1067	885	
BANNU	32709402	1260	384	966	
BESHAM QILA	34729801	1902	580	942	
DAGGAR	34725401	2400	732	924	
DAINYOR	35749300	5749	1752	810	
DOMEL (MUZAFFAR ABAD)	34733402	2250	686	929	
FORT LOCK HART	33709501	6500	1981	786	
GUJAR KHAN	33732301	1500	457	957	
GUNJI BRIDGE	35749999		1560	831	approx. location from Google earth
HUB DAM	25672002	270	82	1003	
KACHURA	35754401	7678	2340	750	
KAGHAN	34739602	7750	2362	748	
KALA BAGH	32719501	700	213	987	
KALAM	35724501	7500	2286	755	
KALLAR SYEDAN	32719501	1700	518	949	
KANDIA	35739998	2815	858	909	
KARIMABAD	36743701	10000	3048	682	
MANGLA DAM	33731601	1000	305	975	
MARDAN	34721001	1000	305	975	
MASSAN	33710601	997	304	975	
MIANI FOREST	25684402		35	1009	approx. location from Google earth
NABISAR ROAD	25690501		25	1010	approx. location from Google earth
OGHI	34735002	3700	1128	878	
PALANDRI	33737601	4600	1402	848	
PHULRA	34733001	3001	915	903	
REHMAN BRIDGE (KOTLI)	33734801_1	2000	610	938	
SAKRAND	26689991		40	1008	approx. location from Google earth
SEHWAN	26674802	121	37	1009	
SHINKIARI	34734201	3250	991	894	
TANK	32702302	800	244	983	
TARBELA	34720701	2000	610	938	
THANO BULA KHAN	25673801	500	152	994	
YUGO	35761101	8098	2468	737	