"El saber de mis hijos hará mi grandeza"

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SIMULATION OF HYDROLOGIC PROCESSES AND HYDRAULIC STRUCTURES USING AN INTERACTIVE APPROACH

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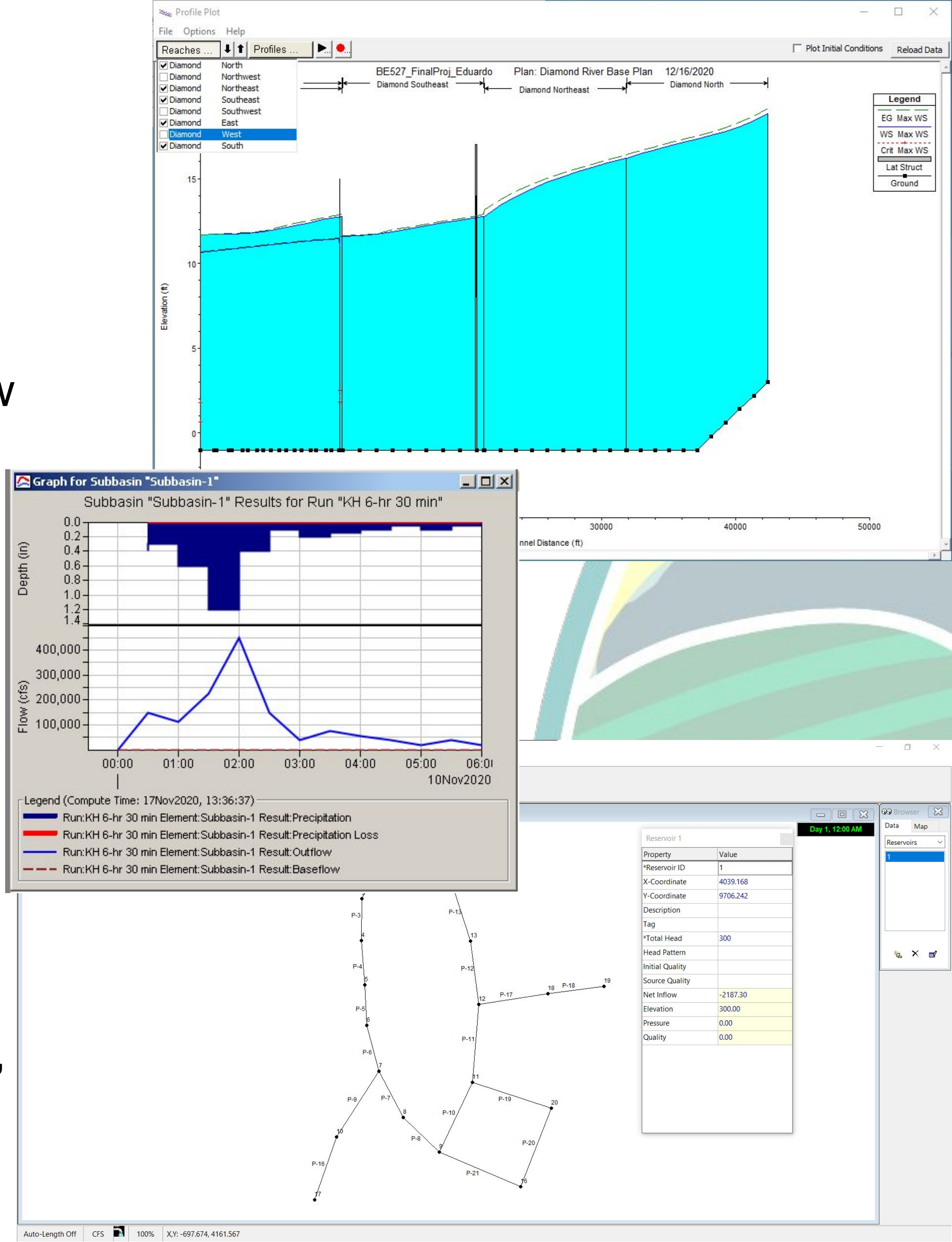
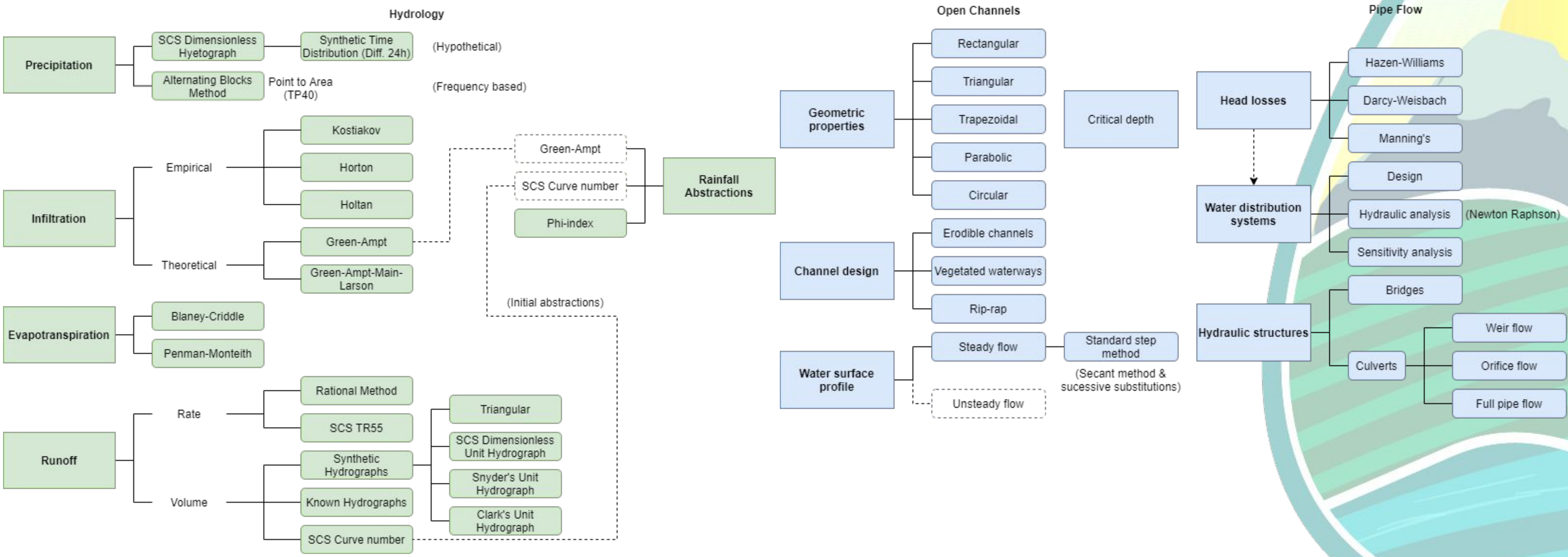
Introduction

- Popular software for hydraulics and hydrologic modeling:
  - HECRAS for river analysis and open channel flow (USACE, 2020)
  - EPANET, simulation of hydraulic and water quality in pressurized pipe networks (Rossman, 2000)
  - HEC-HMS, to simulate hydrologic processes of dendritic watershed systems (USACE, 2021)
- In this work a developing project for a Python 3 software library is presented
- Capable of simulate hydrologic, hydraulic, and irrigation processes.
- Provide a flexible framework that allows further investigation with the utilization of sensitivity analysis, uncertainty analysis, and optimization.



Materials and Methods

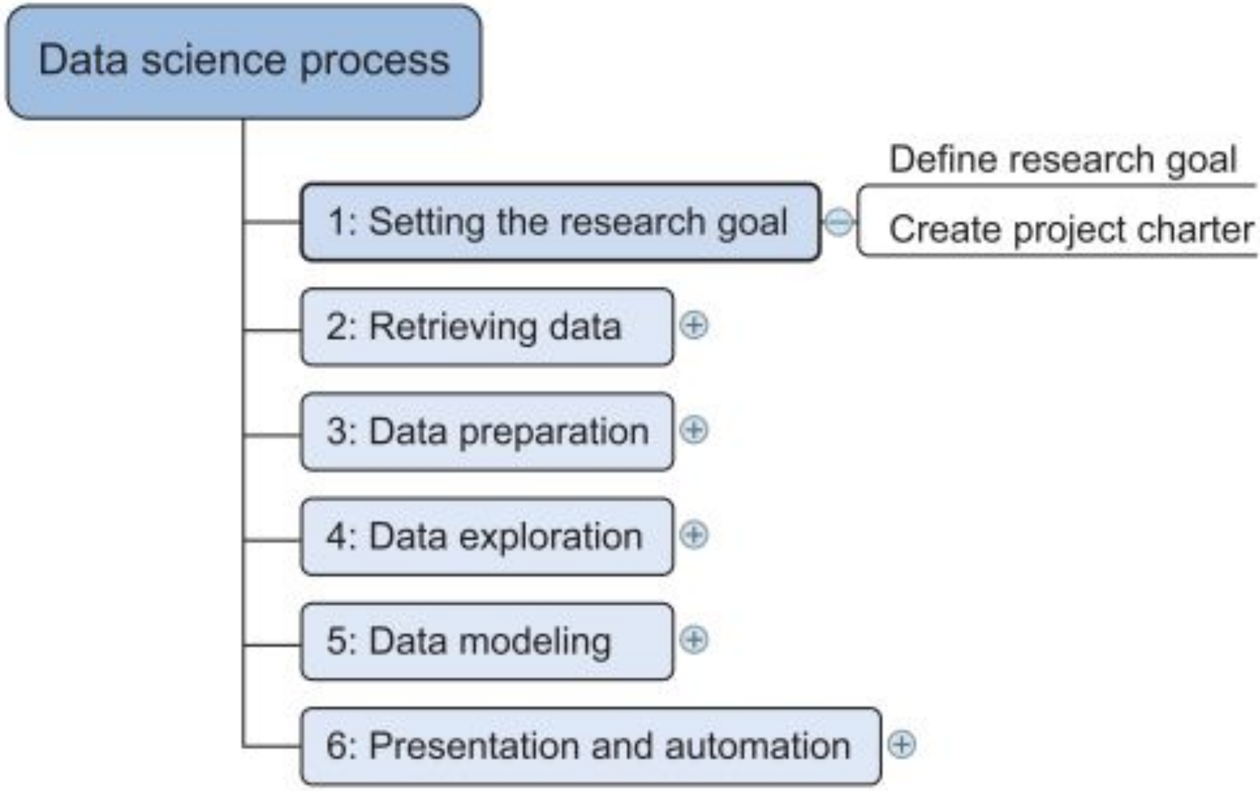
Structure and organization of the library.



Materials and Methods

- **Data science approach for climate.**

- **Big data** is a term for any collection of data sets so large or complex that it becomes difficult to process them using traditional data management techniques.
- **Data science** involves using methods to analyze massive amounts of data and extract the knowledge it contains.
- Data science and big data evolved from statistics and traditional data management but are now considered to be distinct disciplines.



Cielen et al., (2016)

Results and Discussion

Preliminary results: some modules are complete and others are being actively developed.

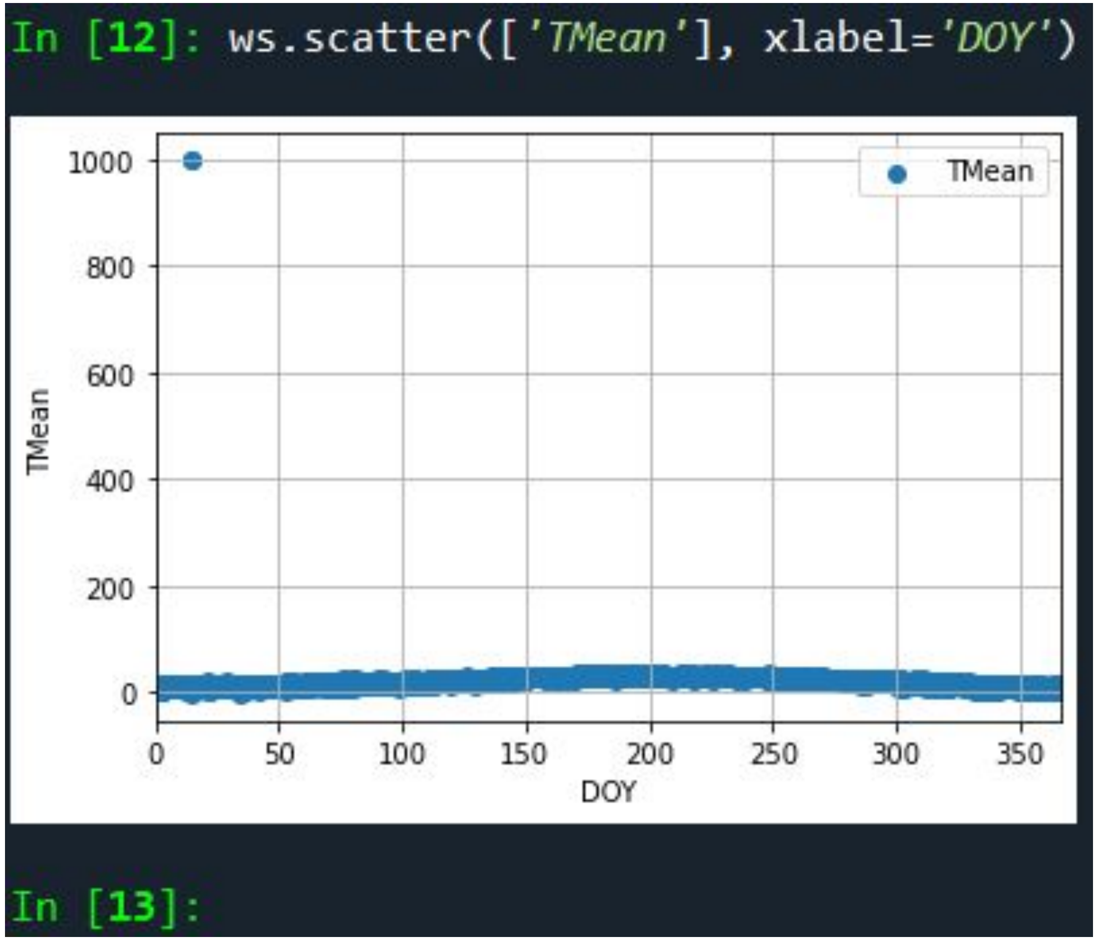
```
Creating weather data for Tucson... successful!
Retrieving data for 2003 (https://cals.arizona.edu/azmet/data/0103rd.txt)... successful!
Retrieving data for 2004 (https://cals.arizona.edu/azmet/data/0104rd.txt)... successful!
Retrieving data for 2005 (https://cals.arizona.edu/azmet/data/0105rd.txt)... successful!
Retrieving data for 2006 (https://cals.arizona.edu/azmet/data/0106rd.txt)... successful!
Retrieving data for 2007 (https://cals.arizona.edu/azmet/data/0107rd.txt)... successful!
Retrieving data for 2008 (https://cals.arizona.edu/azmet/data/0108rd.txt)... successful!
Retrieving data for 2009 (https://cals.arizona.edu/azmet/data/0109rd.txt)... successful!
Retrieving data for 2010 (https://cals.arizona.edu/azmet/data/0110rd.txt)... successful!
Retrieving data for 2011 (https://cals.arizona.edu/azmet/data/0111rd.txt)... successful!
Retrieving data for 2012 (https://cals.arizona.edu/azmet/data/0112rd.txt)... successful!
Retrieving data for 2013 (https://cals.arizona.edu/azmet/data/0113rd.txt)... successful!
Retrieving data for 2014 (https://cals.arizona.edu/azmet/data/0114rd.txt)... successful!
Retrieving data for 2015 (https://cals.arizona.edu/azmet/data/0115rd.txt)... successful!
Retrieving data for 2016 (https://cals.arizona.edu/azmet/data/0116rd.txt)... successful!
Retrieving data for 2017 (https://cals.arizona.edu/azmet/data/0117rd.txt)... successful!
Retrieving data for 2018 (https://cals.arizona.edu/azmet/data/0118rd.txt)... successful!
Retrieving data for 2019 (https://cals.arizona.edu/azmet/data/0119rd.txt)... successful!
Retrieving data for 2020 (https://cals.arizona.edu/azmet/data/0120rd.txt)... successful!

In [8]: ws.data
Out[8]:
      Year  DOY  Station  TMax  ...  ET0  ET0PM  VaporPressure  DewPoint
0     2003    1        1  16.4  ...  2.1    1.8           0.51      -2.6
1     2003    2        1  20.6  ...  2.7    2.3           0.45      -4.3
2     2003    3        1  24.3  ...  2.5    2.1           0.46      -4.0
3     2003    4        1  24.3  ...  2.8    2.5           0.55      -1.5
4     2003    5        1  25.3  ...  2.5    2.2           0.59      -0.6
...    ...  ...      ...   ...  ...  ...    ...            ...       ...
6570  2020  361        1  21.6  ...  2.6    1.6           0.50      -2.7
6571  2020  362        1  24.0  ...  2.2    2.1           0.56      -1.3
6572  2020  363        1  23.4  ...  3.6    3.8           0.62       0.1
6573  2020  364        1  13.4  ...  1.8    1.6           0.70       1.7
6574  2020  365        1  15.8  ...  2.3    1.7           0.45      -4.3

[6575 rows x 28 columns]
```

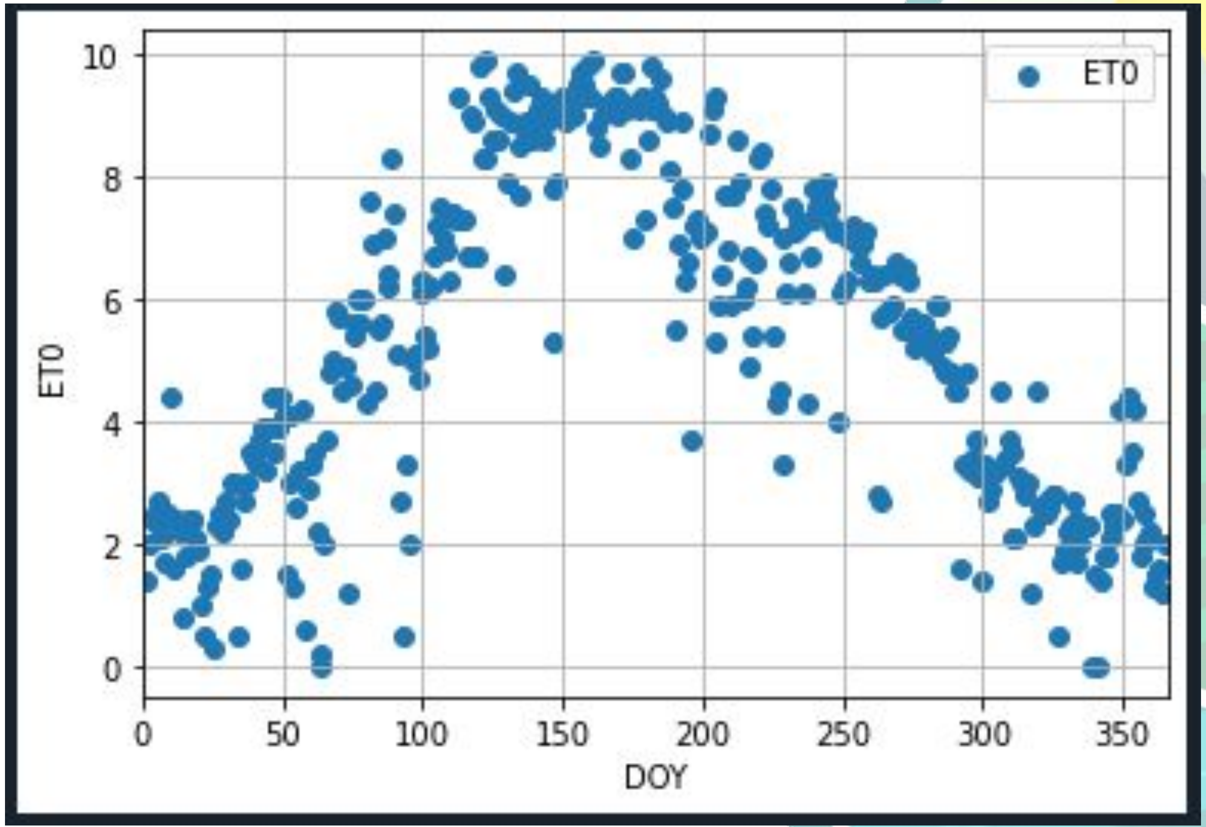
```
In [9]: selection =  ['Year', 'DOY', 'SR', 'TMean', 'RHMean', 'ET0', 'ET0PM']

In [10]: ws.select(selection)

In [11]: ws.data
Out[11]:
      Year  DOY     SR  TMean  RHMean  ET0  ET0PM
0     2003    1  12.35    5.8    61.2  2.1    1.8
1     2003    2  12.72    7.5    54.5  2.7    2.3
2     2003    3  12.71    9.4    48.2  2.5    2.1
3     2003    4  12.68   11.1    49.1  2.8    2.5
4     2003    5  12.57   11.4    50.5  2.5    2.2
...    ...  ...    ...    ...     ...  ...    ...
6570  2020  361  13.46    9.1    48.8  2.6    1.6
6571  2020  362  10.97   11.5    45.4  2.2    2.1
6572  2020  363  11.50   16.2    35.7  3.6    3.8
6573  2020  364   9.95   10.1    57.3  1.8    1.6
6574  2020  365  13.63    5.7    55.0  2.3    1.7

[6575 rows x 7 columns]
```

Data retrieval and preparation using Python standard libraries.

Results and Discussion

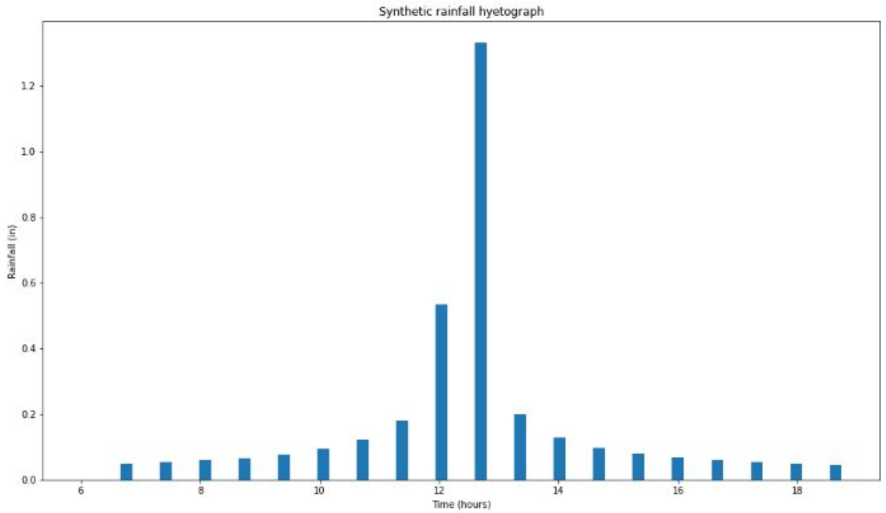
Plots for **data exploration**.

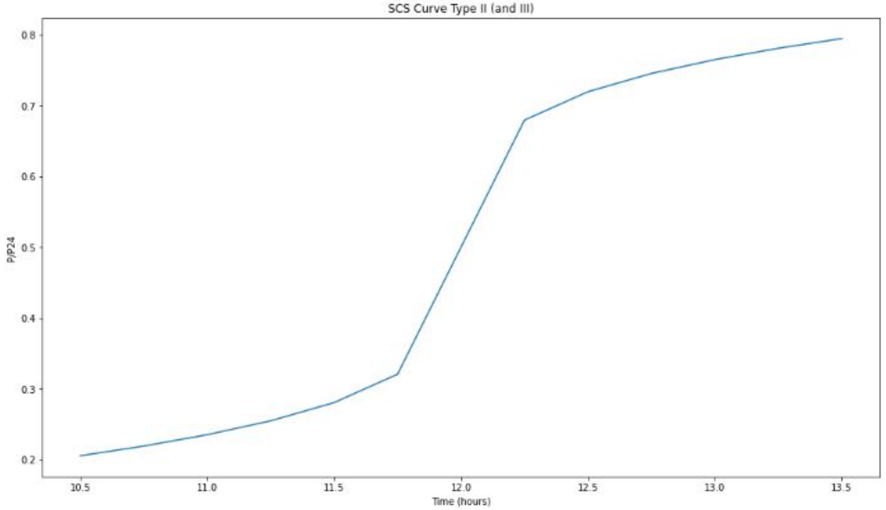




Results and Discussion

Data modeling, using classical techniques to model processes and design hydraulic structures.





Basic hydrologic calculations: a synthetic rainfall hyetograph, and an approximation of SCS Curve Type II

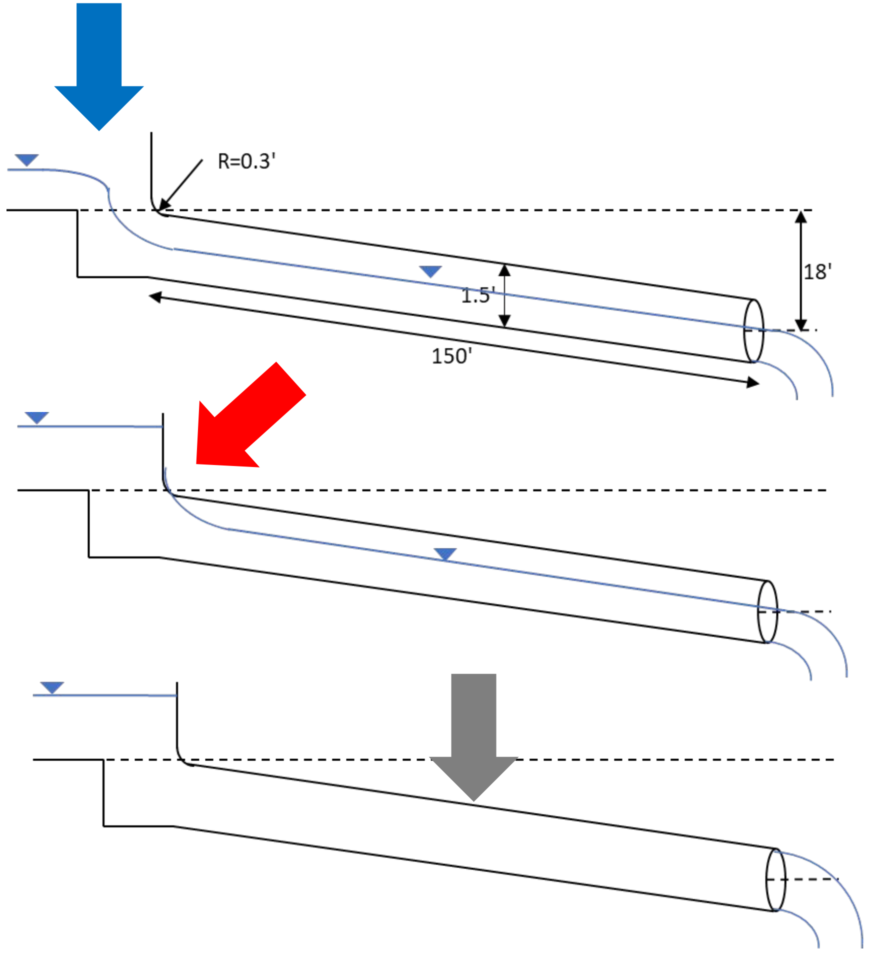
Iter	y	A	R	v	Q	Diff	Accept?
0	0.0100	0.0001	0.0035	0.1379	0.0000	30.0000	False
1	0.0200	0.0004	0.0071	0.2190	0.0001	29.9999	0
2	0.0300	0.0009	0.0106	0.2869	0.0003	29.9997	0
3	0.0400	0.0016	0.0141	0.3476	0.0006	29.9994	0
4	0.0500	0.0025	0.0177	0.4034	0.0010	29.9990	0
5	0.0600	0.0036	0.0212	0.4555	0.0016	29.9984	0
6	0.0700	0.0049	0.0247	0.5048	0.0025	29.9975	0
7	0.0800	0.0064	0.0283	0.5518	0.0035	29.9965	0
8	0.0900	0.0081	0.0318	0.5969	0.0048	29.9952	0
9	0.1000	0.0100	0.0354	0.6403	0.0064	29.9936	0
10	0.1100	0.0121	0.0389	0.6823	0.0083	29.9917	0

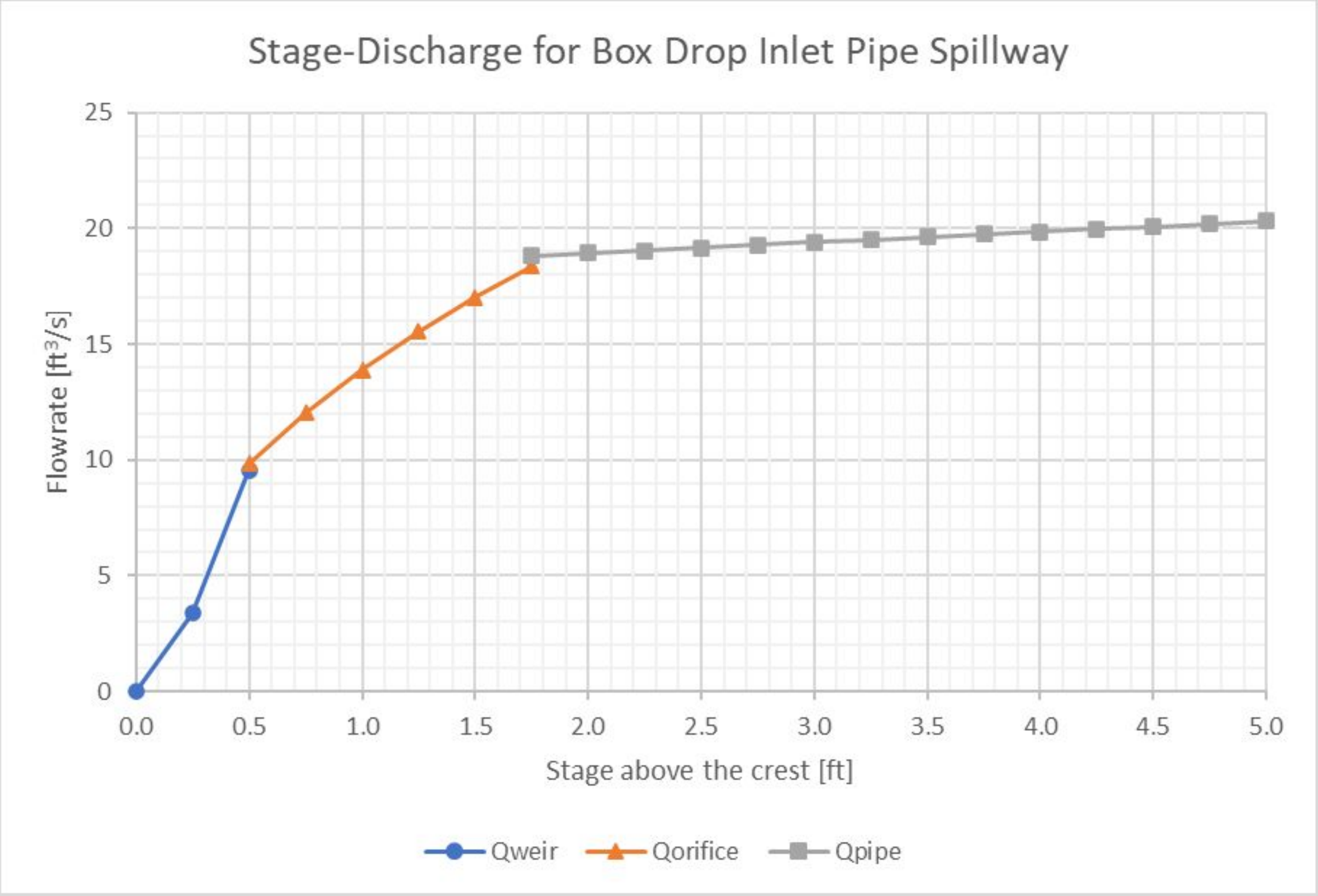
Iter	D	n	phi	d	tau	eta	SFb	Diff	Accept?
0	0.0100	0.0183	42.0000	0.4338	2.7070	55.2125	0.0180	1.4820	False
1	0.0200	0.0206	42.0000	0.4649	2.9013	29.5876	0.0335	1.4665	False
2	0.0300	0.0220	42.0000	0.4842	3.0213	20.5413	0.0482	1.4518	False
3	0.0400	0.0231	42.0000	0.4983	3.1095	15.8556	0.0623	1.4377	False
4	0.0500	0.0240	42.0000	0.5096	3.1797	12.9707	0.0761	1.4239	False
5	0.0600	0.0247	42.0000	0.5189	3.2382	11.0078	0.0895	1.4105	False
6	0.0700	0.0254	42.0000	0.5270	3.2885	9.5818	0.1027	1.3973	False
7	0.0800	0.0259	42.0000	0.5341	3.3327	8.4968	0.1156	1.3844	False
8	0.0900	0.0264	42.0000	0.5404	3.3722	7.6422	0.1283	1.3717	False
9	0.1000	0.0269	42.0000	0.5461	3.4079	6.9508	0.1409	1.3591	False
10	0.1100	0.0273	42.0000	0.5514	3.4405	6.3795	0.1533	1.3467	False

Design of a channel and riprap selection using iterative approach

Applications in engineering

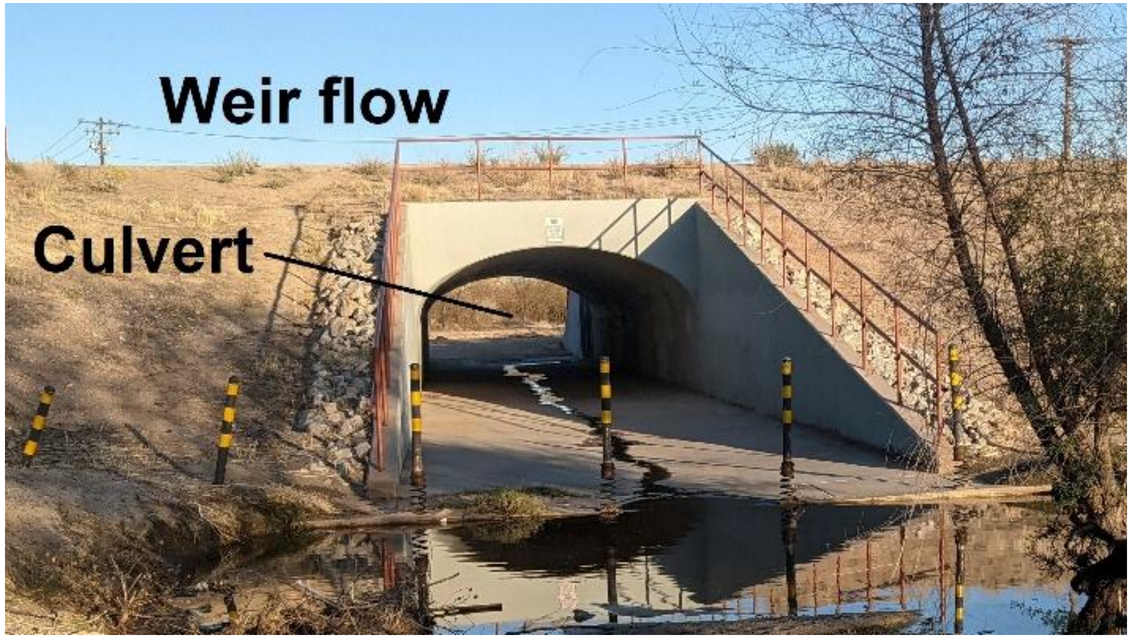
Organizing calculations as desired.





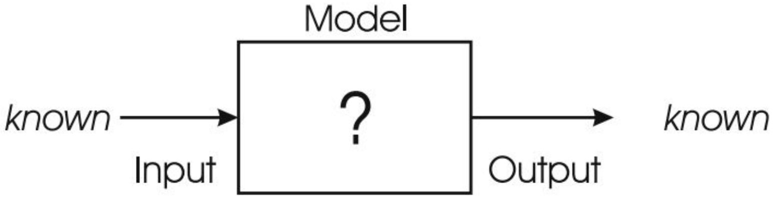
Applications in engineering

Complex structures such as detention ponds also integrate: runoff hydrographs, culverts, weirs, etc.



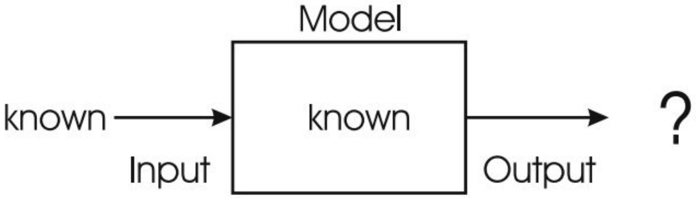
Additional analysis

- **Modeling:**

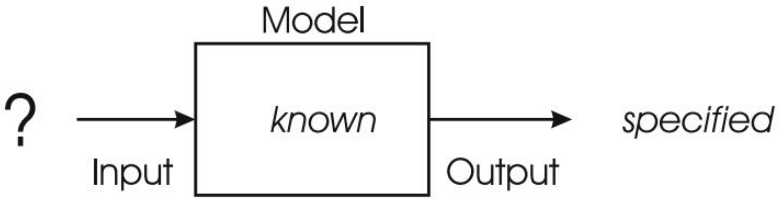


Aim: a library that allows these analysis.

- **Simulation:**



- **Optimization**:



Eiben & Smith, (2015)

- **Sensitivity analysis**, how uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input (Saltelli et al., 2004).
- **Uncertainty analysis**, which focuses rather on quantifying uncertainty in model output (Saltelli, et al., 2008).

Conclusions

- An ongoing development of a software library for performing calculations in a wide set of fields in irrigation, hydraulics, and hydrology.
- The interactive approach is a result of the combination of factors such as scripts are usually run from the source code, Python being an interpreted language, and the IDEs typically used.
- Allow the user to run code step by step, verify intermediate results, and organize the calculations as desired.
- The library is flexible enough so it can be readily adapted to different methods or integrated with other Python modules to allow advanced model analysis, such as sensitivity analysis, uncertainty analysis, and optimization.
- Although the current version of the software is not complete, the finished modules are fully functional and already available for downloading and testing. However, the author insists on executing intensive testing before using the software in production environments or research.

References

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¡GRACIAS!

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