Pipeline Design
Using the Excel spreadsheet

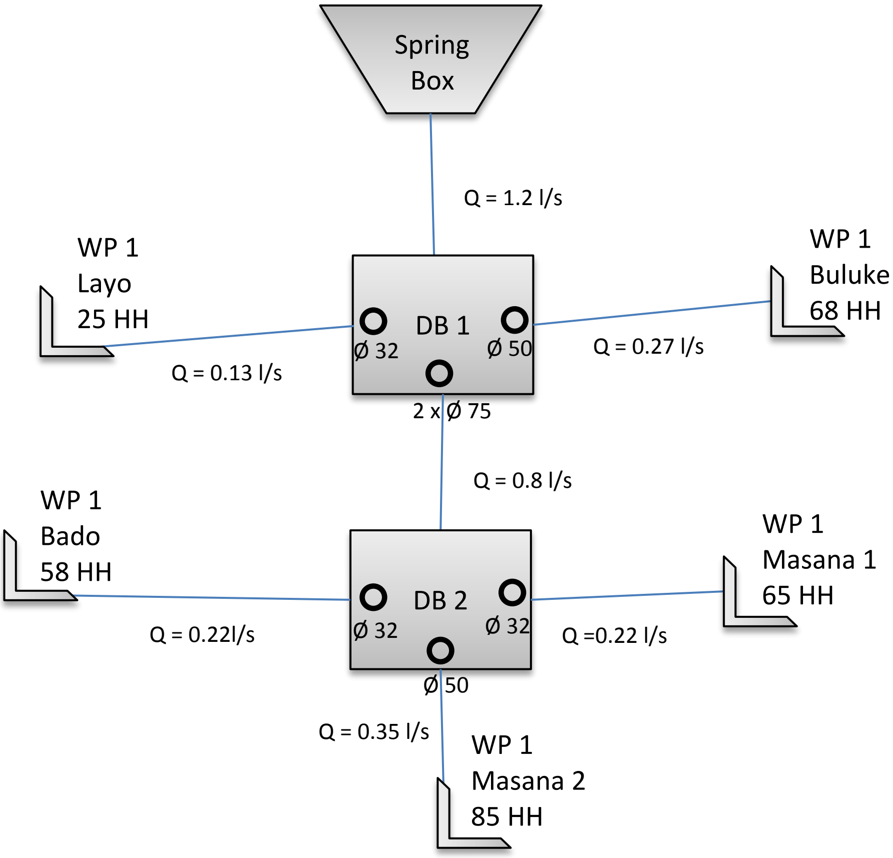
Pipeline design process

I. The sketch

From the very beginning of the design process, a sketch a future network should be drawn. This sketch should be updated at each step of the design process (see “Network design guideline” chapter 4).

It is easier to draw the sketch in the pipeline design sheet, it helps other to understand the design.

Example

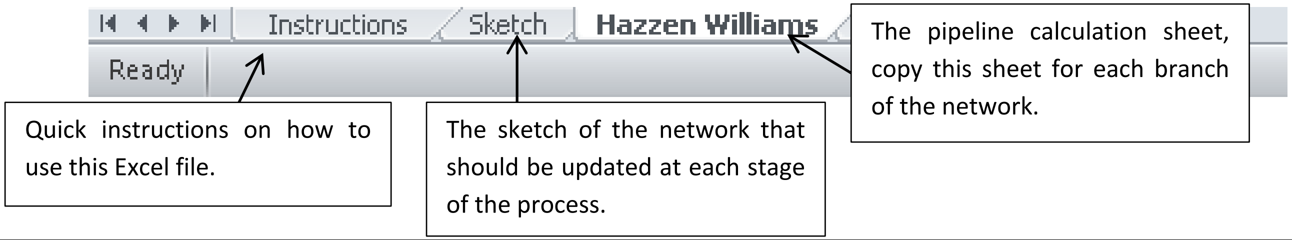


II. Using Topographic Map

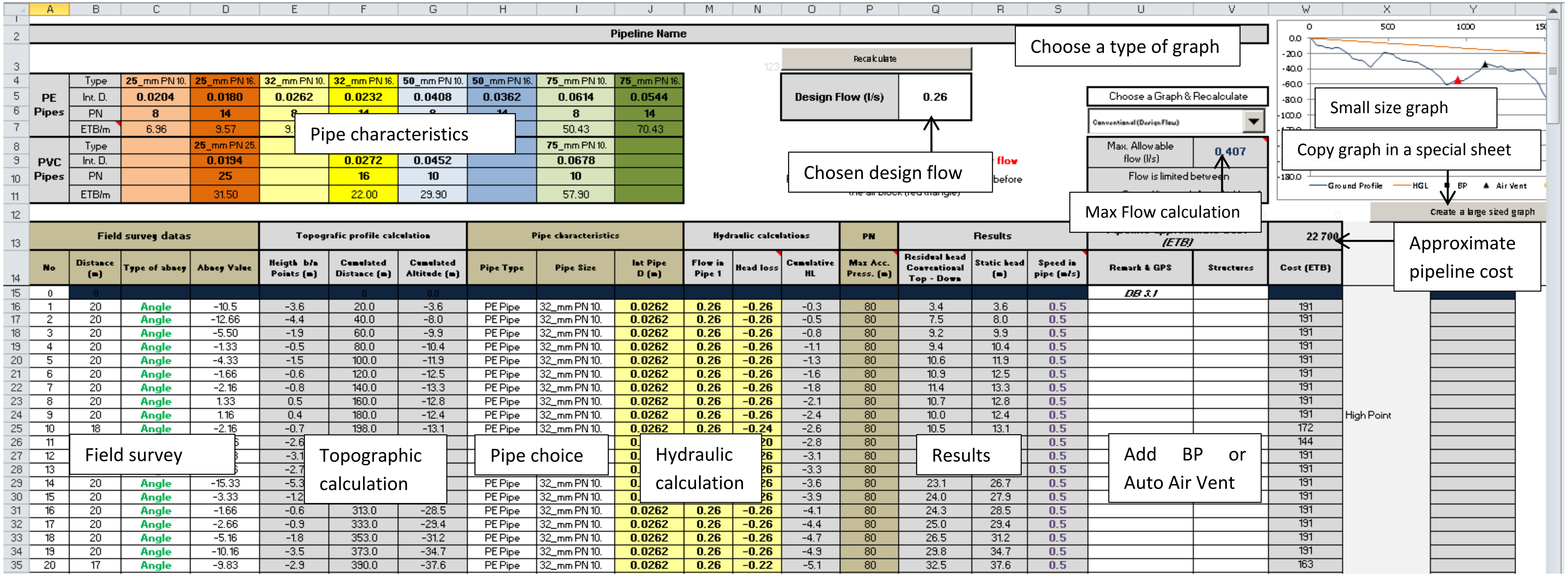
A first sketch on a topographic map from the GPS location of the source and all the WP can help to better direct the topographic survey. See Network design guideline (chapter 4) & Sketching network with QGIS.

III. The pipeline design workbook

The different sheets in the pipeline design workbook



The Hazzen Williams sheet



Only modify the white cells. The rest of the cells will be updated automatically by clicking on the Recalculate or by choosing a type of graph.

1. Pipe characteristics

This table lists all the pipe characteristics needed to make the calculation. Normally this table shouldn't be changed by the user except for the prices that can be updated at every new purchase.

2. Field survey

These 4 columns are used to enter abney level data.

- Type of abney (column "C"): choose the scale according to the abney level (degree or percent)
- Abney Value (column "D"): enter the abney value:
    - In decimal : example 5°20 should be entered =5+20/60 =5.33
    - Negative sign when reading downhill

3. Topographic profile calculation

Using the abney data, the sheet calculates the topographic profiles, no modification should be necessary.

4. Pipe characteristics

For each line, enter the type of pipe (HDPE or PVC), then choose the pipe diameter and PN by selecting the appropriate pipe from the drop down list.

Caution: If not otherwise specified, in Ethiopia, IAF buys:

HDPE 25 mm in **PN 16**
HDPE 32 mm in **PN 10**
HDPE 50 mm in **PN 10**
HDPE 75 mm in **PN 10**

The sheet then shows the chosen pipe inside diameter in column "J". The color of the cell changes to match the color of the pipe in the "Pipe characteristic table".

Caution:

This cell (column "J") shows an error when the pipe type and the pipe name (diameter and PN) do not match:

- Start by choosing a pipe type
- Select from the dropdown list a pipe name (diameter and PN)

5. Chosen design flow

Enter the design flow that will be used for calculation in cell "Q4". **The design flow is the dry season yield.** If not communicate with your coordinator to help you on the design.

6. Hydraulic calculation

The sheet calculates the head loss (HL and cumulated HL) depending on the chosen pipe inside diameter and the chosen design flow, no modification is necessary.

7. Maximum acceptable pressure (PN)

This column shows the maximum acceptable pressure in meter for the chosen pipe.

8. Remark

Detail here specific hydraulic point (Break pressure, gully or river crossing, air vent…). You can also specify geographical reference (church, market, leader house…) this will help situating the topography on the ground.

9. Structures

You can add 2 types of structures

- BP: The following point will be calculated considering that the residual head at the BP is 0.
- Auto Air Vent: This will not modify the conventional HGL calculation, but, it can impact the maximum allowable flow that can go through the pipeline, the real HGL calculation or the location of air block.

10. Max Allowable Flow

Any time you click on Recalculate or you choose a different type of graph, the maximum flow that can be carried through the pipeline is recalculated in cell “V8”. The cells “U11” and “U12” indicate which part of the network is constraining the flow.This is mostly useful to determine the maximal pressure occurring in the pipeline (see **Real HGL (Max Flow) in 12.c)**

11. Cost

The cost is calculated according to the chosen pipe length and the unit cost specified in the “Pipe characteristic table”.

12. Results

You can select three types of graph in cell “Q4”:

a) Conventional (Design Flow)

The residual head is calculated from top to down (column “Q”). The design flow can go through the pipeline if the residual head at the end of each section (BP, Auto Air Vent or End of line) is > 0 m.
The conventional design flow does not represent the reality but allows **checking quickly that there is sufficient residual head at the end of the line.** There must even be excess of head to cover for topographic imprecision and/or mistakes at the end of line:

- > 3 m Line length > 100m
- > 5 m Line length > 500m
- > 10 m Line length > 1 km

Negative pressure will appear in red in the column “Q”. To have a positive pressure at the end of the line, you need to increase the pipe diameter on at least a part of the network.

b) Real HGL (Design Flow)

The residual head is calculated using a VBA macro and gives a more accurate representation of what is happening in reality. If you make change in your design, you have to update the graph by clicking on “Recalculate”.

It considers that the residual head at the end of the pipeline or BP is at 0 and it calculates the HGL from down to top. If the HGL crosses the ground profile and if there is an air entrance at the high point, then the HGL will follow the ground profile. If no air entrance, the pressure will be negative. **This representation is used to check that there is no negative point on the line.**

Negative water pressures in pipe can lead to two problems:

- Negative pressure result in a sucking mechanism: air and water outside the pipe may be sucked into the pipe if there is an entrance. For example, Fittings are not made to withstand negative pressure and polluted water might enter through them.

- Strong negative pressure may flatten or even crush the pipe (as if a truck rolled onto them) as the pipes are not designed to withstand negative pressure. This will introduce perturbations in the flow.

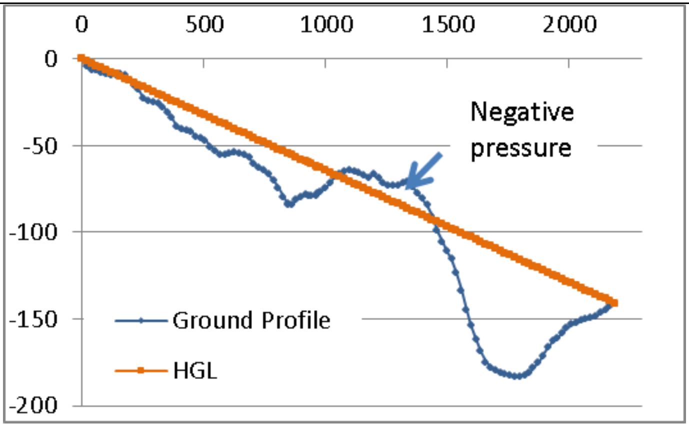
You can locate negative points:

- On the graph: the HGL is going under the ground profile.
- On the column “Y”: the real residual head is negative and appears in red.

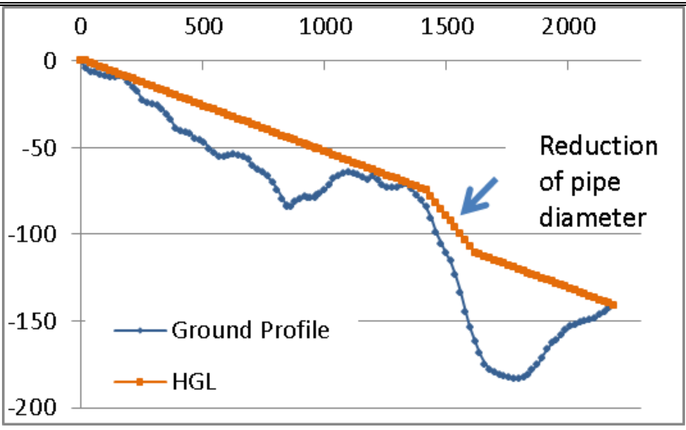
To avoid negative points, you can:

- Use different pipe diameter: Use a fairly larger pipe diameter on low slope and reduce the pipe size diameter on steep slope.
- Add a BP on a high point, in this case a BP[7] is always better than an automatic air vent as it is more durable

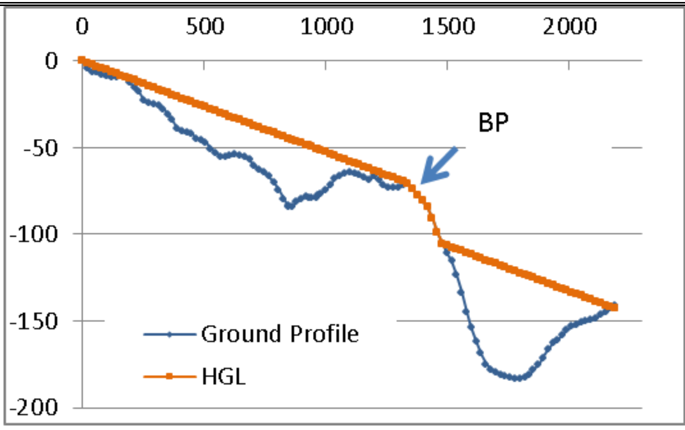
[7] Alternatively a vertical GI pipe can be place at the high point to let air enter into the pipeline. In that case you must check that there will never be positive pressure at that point (using real GHL – Max flow) otherwise the vertical pipe will overflow



A portion of the pipe is under negative pressure



Solution 1 Reduce a portion of the pipe diameter:
By replacing 200 m of the pipeline with a smaller pipe, we avoid negative points (as water pressure increase in the upper part, HGL is higher).



Solution 2: Add a BP
The BP allows air to enter into the pipeline and therefore avoids negative pressure.
This solution is more costly than the Solution 1.

c) Real HGL (Max Flow)

The residual head is calculated from down to top using the maximal allowable flow calculated in cell “V8”. **This representation is used to check that the pressure in the pipeline never exceeds the nominal pressure (PN) of the pipe.** Otherwise pipe might explode.

Portion with too high pressure appear in red in the column “Y”. To solve this problem, several options are possible:

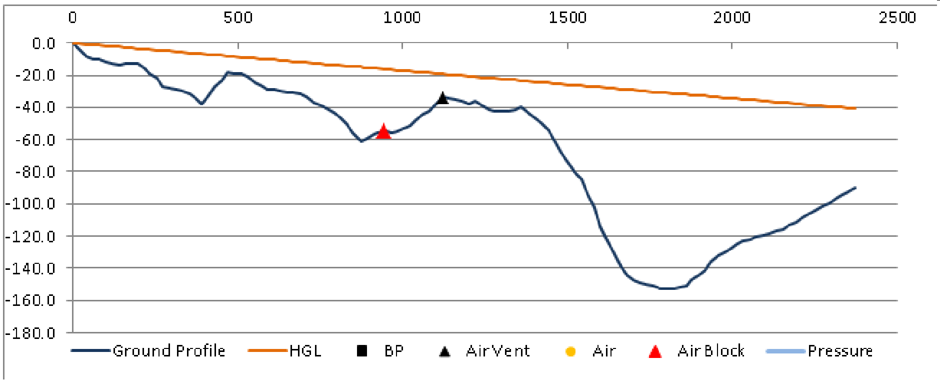
- Change some part of the pipeline to lower diameter in steep area (more head loss → less pressure)
- Add break pressure box: both the static pressure and the residual head will be 0 at the BP level.
- Increase the rated PN of the pipe, this modification should be chosen as the last resort as it will strongly increase the cost and a special order will have to be made.

d) Speed (m/s)

Check the speed in the pipe:

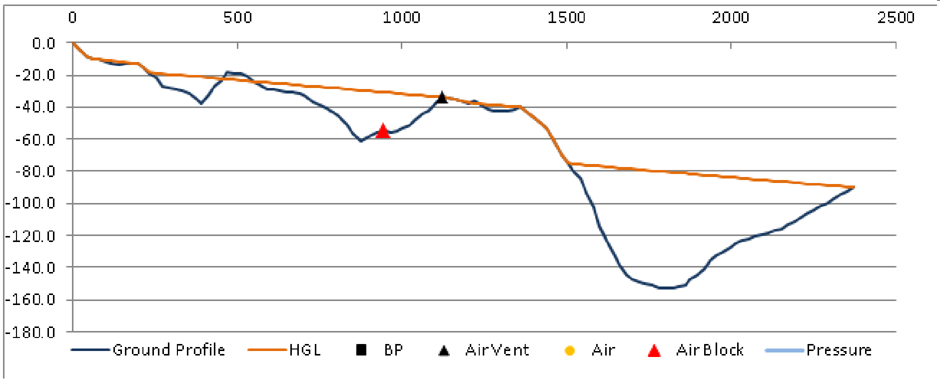
1. **Low speed:** Below 0.5 m/s there is risk of sedimentation, try to avoid in low point and on low slope
   - Below 0.5 m/s the text becomes purple :
2. **High speed:** the water (and particles in suspension) will wear the pipe by friction. It will also increase the risk of water hammer.
   - Above 1.8 l/s the text becomes orange, if possible try to stay below this value
   - Above 3 l/s the text becomes red, the speed is too high, you **must** increase the pipe diameter.

e) 3 graph comparison



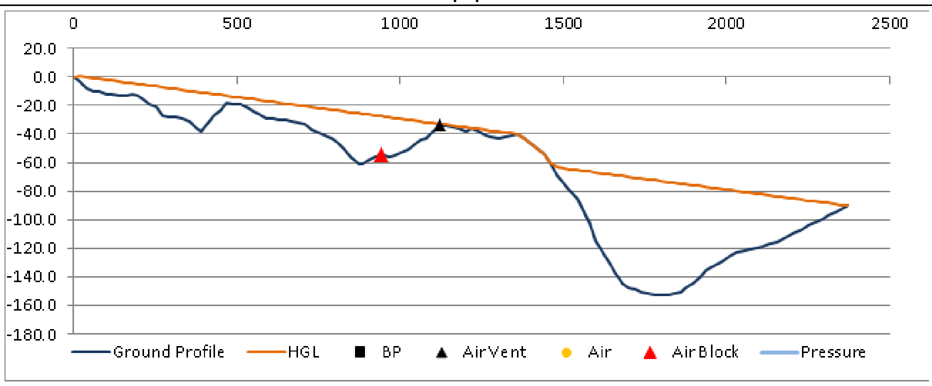
Conventional Mode: Check that the end line HGL is > 0 m

The pipeline can carry the design flow through the pipeline as the residual head at the end of the line exceeds 0 m.



Real HGL (Design Flow): Check that there is no negative point on the line

There is no negative pressure between the Auto Air Vent (Black triangle) and the end of line as the HGL follows the ground profile thanks to the Auto Air Vent. However, the pressure at 500 m point is negative: to avoid this the best method is probably to decrease the pipe diameter just before the air vent to increase pressure in the upper section of the pipeline.



Real HGL (Max Flow): Check that the pressure does not exceed the PN of the pipe

There is no excess of pressure in the pipe

Note: the air vent is not placed correcly, it should be placed on a **marked high point** at around 1250m

13. Air block

A red triangle appears on the graph were the air is blocked in the pipeline. This air block might delay or even completely block the water in the pipeline, and needs to be removed. You can:

- Add a BP[8] on a marked high point, an even higher location should be chosen (preferably with a strong slope on the downstream side)
- In last resort add an Auto Air Vent, also on a specially marked point.

[8] Alternatively a vertical GI pipe can be place at the high point to let air enter into the pipeline. In that case you must check that there will never be positive pressure at that point (using real GHL – Max flow) otherwise the vertical pipe will overflow