In [1]:
```python
import os
os.environ['USE_PYGEOS'] = '0'
import geopandas as gpd
import pandas as pd
import numpy as np
```

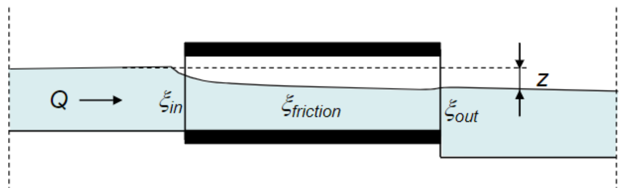
Goal: design of culvert from current area into water storage area

Using: $Q = \mu A\sqrt{2gz} \rightarrow z = (\Sigma\zeta)\frac{u^2}{2g}$

Strikler: $\frac{\delta h}{L} = \frac{u^2}{k^2 R^{\frac{4}{3}}}$

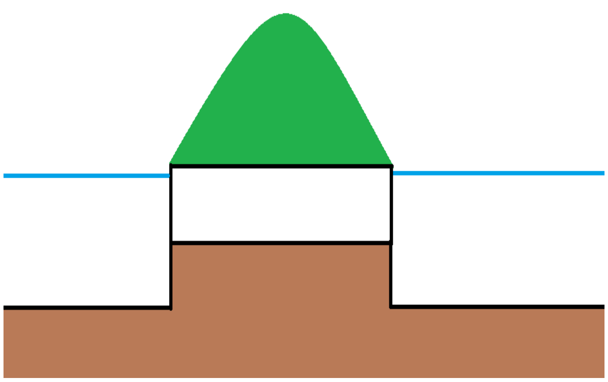
We can rewrite $\zeta_{friction} = \frac{2gL}{k^2 R^{\frac{4}{3}}}$

And:



using $z_{max} = 5mm$, $\zeta_{in} = 0.3, \zeta_{out} = 1$

design situation, with of culvert topview in red on the right



From Sobek we know the discharge should be around $0.56[m^3/s]$ in order to deal with the large amounts of water

$$A = 0.25D^2\pi$$

$$v = Q/A$$

In [2]:
```
Q = 0.56 # m^3/s
k = 50   # m^(1/3)/s - for rought concrete culvert
zeta_in = 0.6
zeta_out = 1
```

In [3]:
```
culvert = gpd.read_file("new_culvert.gpkg",crs="EPSG:28992")
L = culvert.iloc[0]['length']
print(f'{L:.2f}m')
```

```
42.82m
```

In [4]:
```
def zeta_friction(L, D, k, Q):
    A = 0.25 * D**2 *np.pi
    R = A / (np.pi * D)
    u = Q / A
    zeta_f = (2 * 9.81 * L) / (k**2 * R**(4/3))
    return zeta_f, u
```

In [5]:
```
D = 0.2 # m
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

```
with a diameter of 0.2m yields a headloss of 321.34m
```

In [6]:
```
D = 0.4 # m
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

```
with a diameter of 0.4m yields a headloss of 8.95m
```

increase to 4 culverts instread of one

In [7]:
```
Q = 0.56/4 # m^3/s
```

```
D = 0.8 # m
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

```
with a diameter of 0.8m yields a headloss of 0.02m
```

In [8]:
```
Q = 0.56/4 # m^3/s
D = 1.0 # m
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z*1000:.4f}mm')
```

```
with a diameter of 1.0m yields a headloss of 6.0465mm
```

In [9]:
```
Q = 0.56/4 # m^3/s
D = 1.13 # m - sobek has this size availible
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z*1000:.4f}mm')
```

```
with a diameter of 1.13m yields a headloss of 3.3898mm
```

Thus we need 4 culverts of 1100mm in diameter to be able to supply the water storage areas with the peak flow.

implementation: Air pocket: minimal 0.10 m at the normative discharge for the passage of debris The inner bottom of the culvert is constructed at 10% of the diameter under the canal bottom with a max of 0.1 m