Identification of a problem due to engineered open channel flows in "Kotiyagala Tank"

Wila Oya that commences its journey from the Helabada-Bowitiya mountain range in Monaragala joins the eastern sea at Panama in Ampara District. Wila Oya catchment gets its importance because its development history dates back to Dutugemunu era. Major irrigations schemes that are currently in operation in the Wila Oya catchment are Ethimale Wawa, Kotiyagala Wewa and Panama Wawa reservoirs.

According to above brief explanation about Monaragala areas tanks consider kotiyagala Tank to our analysis. There is information to believe that the Kotiyagala in Wila Oya basin also a historical irrigation reservoir. After restoring the reservoir in 1960 people in the area who had been engaged in Chena cultivation has been given lands under the scheme, by the Irrigation Department. There are about two hundred families in the scheme cultivating 450 acres of land.

Now you can see the earth footage view of Kotiyagala reservoir by using google map location.

- Area of the Kotiyagala reservoir : 12.9 sq mils (8.322564E-9 sq meter)
- Capacity (gross storage) of Kotiyagala : 2116.68 Ac ft (2610882.446 cubic meter)

Characteristics of flow channel

1. Open channel flow for vegetation growth

- Open-channel flow often serves as a water source for vegetation. The consistent supply of water in rivers, streams, and canals supports plant growth, especially in agricultural lands where irrigation from open channels is essential for crop cultivation.
- Open-channel flow can contribute to maintaining moisture levels in adjacent soils. Even after water levels recede, the moisture retained in the soil due to the proximity of the channel can support vegetation during dry periods.

2. Open channel flow for social economic activities

- Open channels serve as a source of water for communities, supplying water for drinking, sanitation, and household needs. Reliable access to clean water improves public health and enhances living conditions, particularly in rural areas.
- Open-channel flow is essential for irrigation, providing water for agricultural lands. This supports crop cultivation, boosts agricultural productivity, ensures food security, and generates income for farming communities. It also enables the growth of cash crops, enhancing economic opportunities.

Actually we are very happy to inform that we could get lots of information about the Kotiyagala tank by the Mr.N.M.I.P.Samarasinghe who is the Divisional Assistant of the Divisional Irrigation Engineer's Office in Monaragala. He also provided a current meter to measure the speed of the flowing water through the open channel. Not only that, he gave very important information and historical background of the tank to achieve our target.

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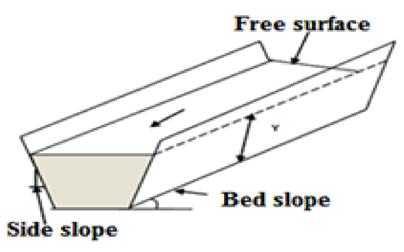
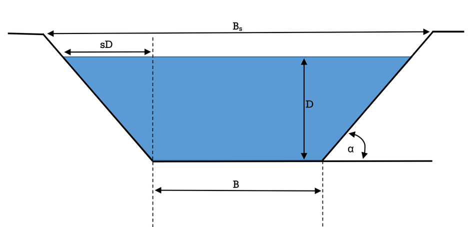
We could get helps from other persons. Some villagers also gave their supports to us as much as they can. Actually the road to Kotiyagala tank was very difficult, but with the support of the villagers, we were able to reach there.

We could see, the Kotiyagala reservoir has trapezoidal cross sectional shape flow channel.





Water flow area $= \frac{1}{2} \times D[B + (B + 2D\cot\alpha)]$

$= 0.3(1.1+0.3\times\frac{0.9}{0.7})$

$= 0.446 m^2$

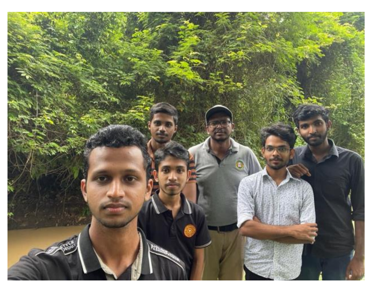
Channel wall angle $= \tan^{-1}(\frac{0.7}{0.9})$

$= 37^0 52'$

Wetted perimeter (P) $= B + \frac{2D}{\sin\alpha}$

$= 1.1 + \frac{2(0.3)}{\sin 37^0 52'}$

$= 2.077m$



Group members

Cannel shape

Hydraulic radius (R) $= \frac{\text{Water flow area}}{\text{Wetted perimeter}}$

$= \frac{0.446}{2.077}$

$= 0.215m$

Using current meter

Hydraulic depth (D) $= \frac{\text{Water flow area}}{\text{Top width of flow}}$

$= \frac{0.446}{(1.1+0.6\times\frac{0.9}{0.7})}$

$= 0.234m$

We roughly measured flow rate of open channel flow and considered specific length of open channel. Using small floating body, we measure required time to pass considered specific length of open channel. We calculate approximate value for velocity of the flow, dividing considered length by measured time. We measured set of readings and finally calculated an average value. Measured values are as mentioned below,

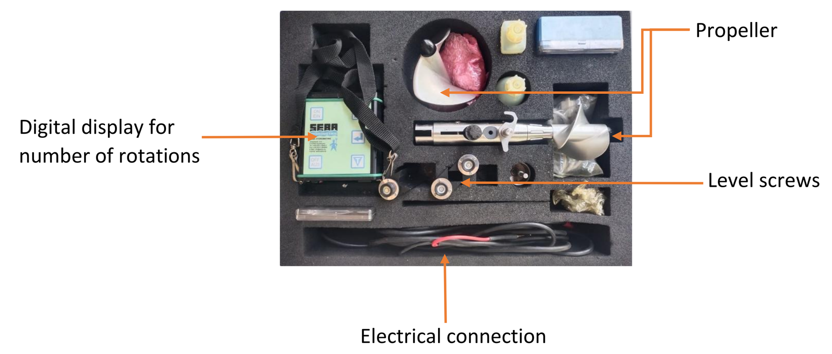
Considered length of water flow = 20 m

	Time(s)	Mean velocity(ms^{-1})
1	56.45	0.354
2	60.59	0.330
3	62.22	0.321
4	60.01	0.333
5	50.92	0.392

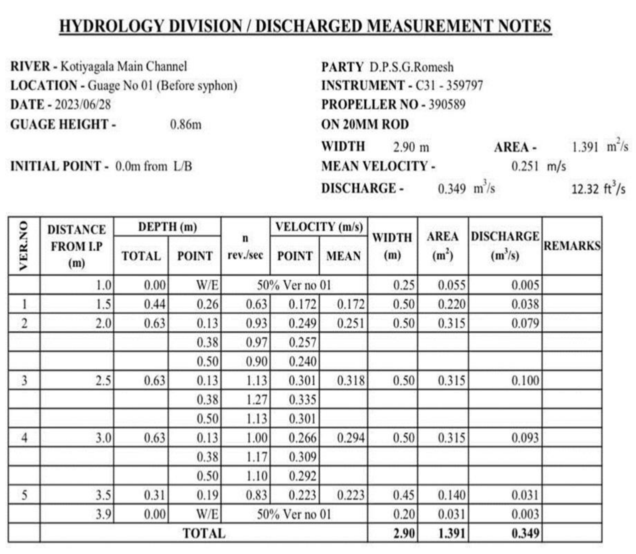
Mean velocity of flow = (0.354+0.330+0.321+0.333+0.392)/5

= 0.346 ms^{-1}

And also, we measured water flow rate using current meter as well. Current meter is a device used to measure water flow velocity in rivers, stream or other bodies of water.



We measured flow rate of open channel using current meter. But the current meter was not proper working condition. Divisional irrigation engineer, MR. W.H.R.P. Indrajith is provided a current meter to us to measure the flow rate of the open channel. We got know more details about current meter, its working mechanism and how to measure flow rate using current meter.



HYDROLOGY DIVISION / DISCHARGED MEASUREMENT NOTES

RIVER - Kotiyagala Main Channel
LOCATION - Guage No 01 (Before syphon)
DATE - 2023/06/28
GUAGE HEIGHT - 0.86m
INITIAL POINT - 0.0m from L/B

PARTY D.P.S.G.Romesh
INSTRUMENT - C31 - 359797
PROPELLER NO - 390589
ON 20MM ROD
WIDTH 2.90 m AREA - 1.391 m^2/s
MEAN VELOCITY - 0.251 m/s
DISCHARGE - 0.349 m^3/s 12.32 ft^3/s

VER.NO	DISTANCE FROM I.P (m)	DEPTH (m) TOTAL	DEPTH (m) POINT	n rev./sec	VELOCITY (m/s) POINT	VELOCITY (m/s) MEAN	WIDTH (m)	AREA (m^2)	DISCHARGE (m^3/s)	REMARKS
	1.0	0.00	W/E	50% Ver no 01			0.25	0.055	0.005	
1	1.5	0.44	0.26	0.63	0.172	0.172	0.50	0.220	0.038	
2	2.0	0.63	0.13	0.93	0.249	0.251	0.50	0.315	0.079	
			0.38	0.97	0.257					
			0.50	0.90	0.240					
3	2.5	0.63	0.13	1.13	0.301	0.318	0.50	0.315	0.100	
			0.38	1.27	0.335					
			0.50	1.13	0.301					
4	3.0	0.63	0.13	1.00	0.266	0.294	0.50	0.315	0.093	
			0.38	1.17	0.309					
			0.50	1.10	0.292					
5	3.5	0.31	0.19	0.83	0.223	0.223	0.45	0.140	0.031	
	3.9	0.00	W/E	50% Ver no 01			0.20	0.031	0.003	
	TOTAL						2.90	1.391	0.349	

Finally chief engineer provided us previously measured values of flow rate because of current meter was not working condition. Measured values are as below.

Flow area $= 1.391\ m^2$

Mean velocity $= \frac{0.172 + 0.251 + 0.318 + 0.294 + 0.223}{5}$

$= 0.251\ ms^{-1}$

Discharge rate $= 1.391 \times 0.251$

$= 0.349\ m^3s^{-1}$

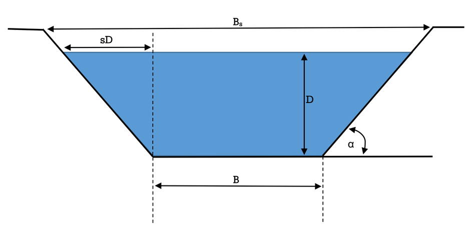
Problem

The lake cannot supply water to paddy fields with sufficient speed and quantity. The water is not flowing through the open channel at sufficient speed and quantity. Therefore, water does not flow for all the paddy fields that depend on the reservoir. Therefore, farmers have a problem. That is water is not enough for their paddy fields.

There are some another problems that can be seen near the open channel that is affected to discharge rate.

1. In some places of the open channel, there were some water leakages. Due to this leakage, the capacity of the open channel is decreased. Also speed of the water is decreased.
2. Due to erosion of open channel, the open channel is filled from the soil. The soil is in some places of open channel. It is barrier to the flow of water. Then the speed of water is decreased.
3. In the open channel, the latter part was not concreated. Therefore, the water is absorbed to the soil. It is caused to our problem.
4. In some places, the open channel was covered from grass. Therefore, the speed of the water is decreased. Grass was barrier to the flow of the water.

In our opinion, we think this open channel's size and shape are completely economically.



$B_s = B + 2sD$ (s is constant)

$A = \frac{1}{2}[B + (B + 2sD)] \times D$

$A = (B + sD)D$

Then,

$B = \frac{A}{D} - sD$

If the wetted perimeter is p,

$P = B + 2D\sqrt{1 + s^2}$

$P = \frac{A}{D} - sD + 2D\sqrt{1 + s^2}$

For a given A and the channel slope, P will be minimum.

Differentiate p with respect to D,

$\frac{dp}{dD} = -\frac{A}{D^2} - s + 2\sqrt{1 + s^2}$

$\frac{dp}{dD} = 0$

$-\frac{A}{D^2} - s + 2\sqrt{1 + s^2} = 0$

$-\frac{(B+sD)D}{D^2} - s + 2\sqrt{1 + s^2} = 0$

$B = 2D\sqrt{1 + s^2} - 2sD$

By substituting B value,

$A = (2D\sqrt{1 + s^2} - 2sD + sD)D$

$P = 2D\sqrt{1 + s^2} - 2sD + 2D\sqrt{1 + s^2}$

$R = \frac{A}{P}$

By substituting above A and P values we can obtain,

$R = \frac{D}{2}$

- So that means to have maximum efficiency of this open channel, Hydraulic Radius (R) should be equal to the half of Hydraulic Depth (D). This channel has not maximum efficiency because $R > \frac{D}{2}$.

An open channel approach enhances environmental resilience, promotes social inclusivity, and offers economic advantages, making it a sustainable choice for water management in a given area.

Environmental Aspect:

- Open channels allow water to flow naturally, promoting ecosystem health and biodiversity. Compared to mechanical systems, open channels often require less energy for water movement, reducing the environmental footprint.

Social Aspect:

- Open channels can provide nearby communities with access to water resources, addressing social equity and improving overall quality of life. Well-designed open channels can create recreational spaces, fostering community engagement and well-being.

Economic Aspect:

- Open channels typically have lower construction and maintenance costs compared to enclosed systems, contributing to economic efficiency. Water from open channels can be utilized for agriculture, supporting local economies and contributing to food security.

Solutions

Optimize Channel Geometry and Channel Linings:

- Adjust the channel dimensions, such as bottom width and side slope, to achieve an optimal hydraulic radius. This cause to increase flow efficiency.
- Use smooth and erosion-resistant channel linings to reduce frictional losses and improve flow efficiency.

Maintain proper Slope along the channel flow:

- Make sure the channel is not too steep or too flat. If it's too steep, water rushes too fast, causing problems. If it's too flat, water moves sluggishly, which is also not good. Find a slope that lets the water flow at the right speed for what you need. This helps things work smoothly and efficiently.

Consider Vegetative Solutions:

- By using turfs on the sides of the channel we can keep the soil stable, prevent erosion, and make the flow of water work better. It's like having a natural way to protect the channel and enhance flow efficiency.

Reference

- *Flow section channels - geometric relationships* (no date) *Engineering ToolBox*. Available at: https://www.engineeringtoolbox.com/flow-section-channels-d_965.html (Accessed: 26 November 2023).
- Kamaladasa, B. (1969) *Ancient reservoirs of ethimale, Kotiyagala and Panama*, *AmazingLanka.com*. Available at: https://amazinglanka.com/wp/irrigation-ethimale-en/ (Accessed: 26 November 2023).
- *Irrigation engineering 4(3+1)* (no date) *IE: LESSON 12 Design of Open Channel*. Available at: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=1975 (Accessed: 26 November 2023).

Author Statement

- 22/ENG/109 – Basic Introduction and Characteristic flow Channel
- 22/ENG/112 – The calculation part of the trapezoidal flow Channel
- 22/ENG/126 – Problems of the Open Channel
- 22/ENG/137 – The efficiency part of the Channel
- 22/ENG/150 – Engineering solutions for problems of the Channel