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CIVE 717

Homework 4

5 May 2022

1. Problem 14.3

Estimate the scour depth below a sluice gate with a gate opening of 1-meter. The bed material is gravel with d_{50} = 5 mm and d_{90} = 7mm. The upstream water level is 10 m, and the downstream water level is 5 m. Determine the flow velocity, assuming conservation of energy on both sides of the gate.

Equation 1: The flow velocity in the vena contracta

$$V_1 = \sqrt{2gh} = \sqrt{2 * 9.81 * 5} = 9.9\ m/s$$

Equation 2: The unit discharge through the gate

$$q = Vh = 9.9 * 1 = 9.9 \frac{m^2}{s}$$

Equation 3: Outflow Velocity

$$V_2 = \frac{q}{h_t} = \frac{9.9}{5} = 1.98\ m/s$$

Equation 4: submerged jet scour coefficient

$$K_{sj} = 15$$

Equation 5: Scour depth using Equation 14.5

$$\Delta z = K_{sj} y_j \left(1 - \frac{V_2}{V_1}\right) = 15 * 1 * \left(1 - \frac{1.98}{9.9}\right) = 12\ m$$

The scour depth is deeper here than with a larger gate opening. In order to properly design and plan for scour at the structure, the maximum scour considering the full range of gate openings would need to be considered.

Problem 2

Problem Statement

Solve Problem 14.9

Problem 14.9

Reevaluate the pier scour depth from Example 14.5 should the flow alignment against the pier change to 20˚ in the coming years.

Solution

$$Fr_1 = \frac{V_1}{\sqrt{gh_1}} = \frac{3.75\,\frac{m}{s}}{\sqrt{9.81\,\frac{m}{s^2} * 2.8m}} = 0.71$$

K_1 = 1.1 for rectangular piers

$$\frac{L_p}{a} = \frac{12}{1.5} = 8$$

$$K_2 = \left(\cos\theta_p + \frac{L_p}{a}\sin\theta_p\right)^{0.65} = (\cos 20^\circ + 8\sin 20^\circ)^{0.65} = 2.33$$

K_3 = 1.1

$$\Delta z = 2.0K_1K_2K_3\left(\frac{a}{h_1}\right)^{0.65} Fr_1^{0.65}h_1 = 2.0 * 1.1 * 2.33 * 1.1 * \left(\frac{1.5m}{2.8m}\right)^{0.65} 0.71^{0.43} * 2.8m = 9.08m$$

Problem 3

Subject: Dissolved Oxygen

Given - Problem 13.7

Use Example 13.1 for DO in Colorado Streams with the following parameters:

1. Arrhenius Constant, θ_A = 1.047
2. Velocity = 1 m/s
3. Depth = 3m
4. CBOD, Lo = 20 mg O2/l
5. Oxygen Depletion Rate, k1 = 0.1/day at 20 deg C doubles for evert 10deg C increase in temperature
6. Reaeration Constant, k2 = 0.6/day, constant at all temps
7. South Platte River, Denver, CO

Find

Determine the dissolved oxygen concentration as a function of the downstream distance at temperatures from 10degC to 30degC.

Solution

For the following temperatures, 10°C, 20°C, 25°C, and 30°C, define the following:

1. Determine DO_{sat} using Figure 13.11 (Julien, River Mechanics)
   $DO_{sat} = [14.7 - 0.0017(Alt)]\, e^{-0.0225T^{o}_{C}}$
2. Determine oxygen depletion rate, k_1 assuming relationship to temperature below:

$$k_1 = .1 * A^{T-20^{o}_{C}}$$, where A = θ_A = 1.047

Temp, degC	DOsat O2/l	k1/day
10	9.57	0.06
20	7.64	0.10
25	6.83	0.13
30	6.10	0.16

3. Determine distance at which the dissolved oxygen is at a minimum, X_{max} (assumes initial oxygen deficit, Do = 0)

$$X_{max} = \frac{V}{k_2 - k_1} ln \left\{ \frac{k_2}{k_1} \left[1 - \frac{Do(k_2 - k_1)}{k_1 L_o} \right] \right\}$$

4. Determine oxygen deficit, D_x

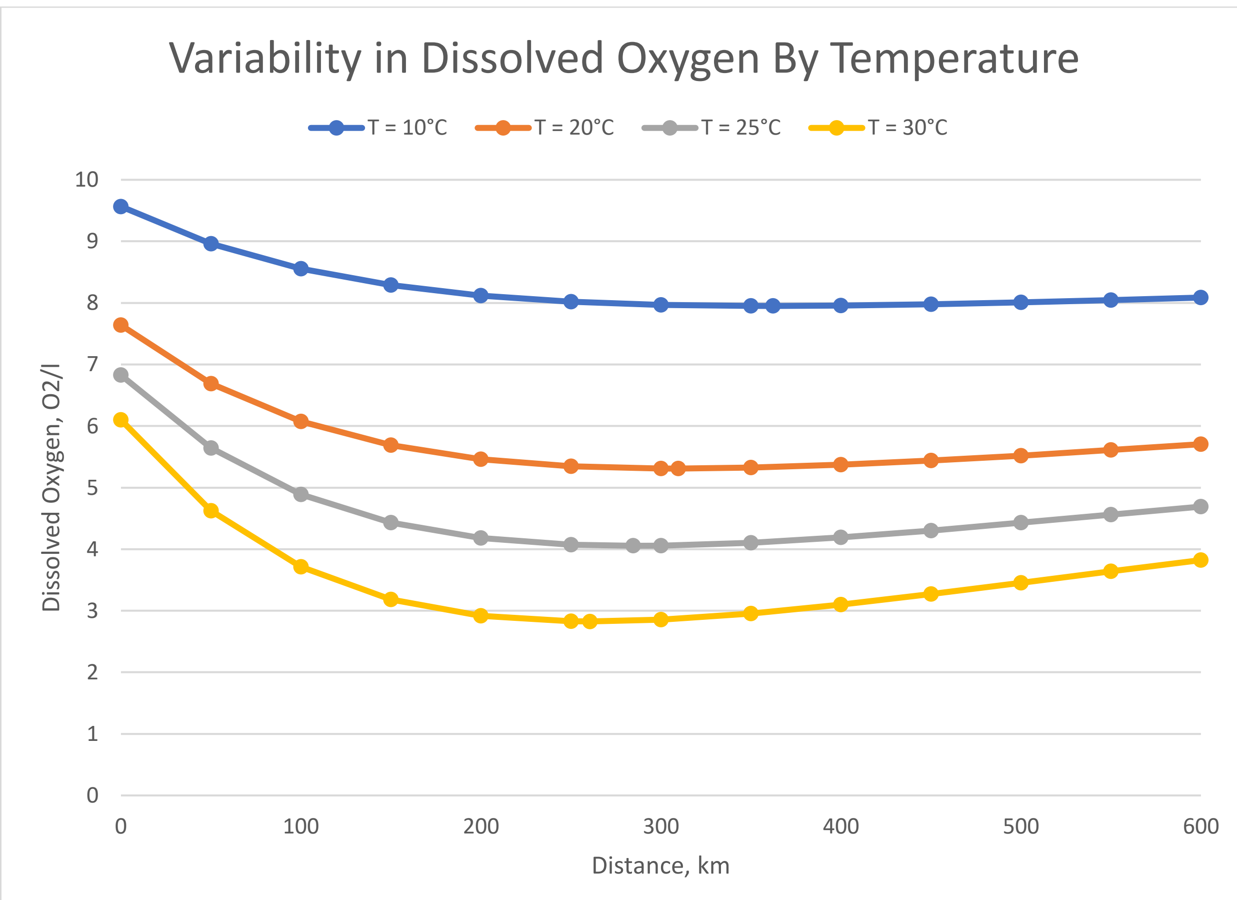
$$D_x = \frac{k_1 L_o}{(k_2 - k_1)} \left(e^{-k_1 x/V} - e^{-k_2 x/V} \right) + D_o e^{-k_2 x/V}$$

5. Determine dissolved oxygen concentrations, DO_x

$$DO_x = DO_{sat} - D_x$$

8. The table below shows the maximum distance at which the dissolved oxygen is at a minimum and the associated oxygen deficit and dissolved oxygen concentrations. These points were plotted on the graph below, along with the dissolved oxygen as a function of distance. The processes was done every 50km. The results using a Arrhenius Constant, θ_A = 1.047 instead of 1.07 as shown in Example 13.1. The results were similar at the shorter distances, but as the distances get larger, the dissolved oxygen using θ_A = 1.047 are lower than the Example 13.1 results. The results are also flatter in comparison.

Temp, degC	Dosat O2/l	k1/day	Xmax (km)	Dx Max (O2/l)	DOx (O2/l)
10	9.57	0.06	362.30	1.62	7.951
20	7.64	0.10	309.62	2.33	5.309
25	6.83	0.13	284.63	2.77	4.055
30	6.10	0.16	260.64	3.27	2.827



13.3 Aquatic Environment

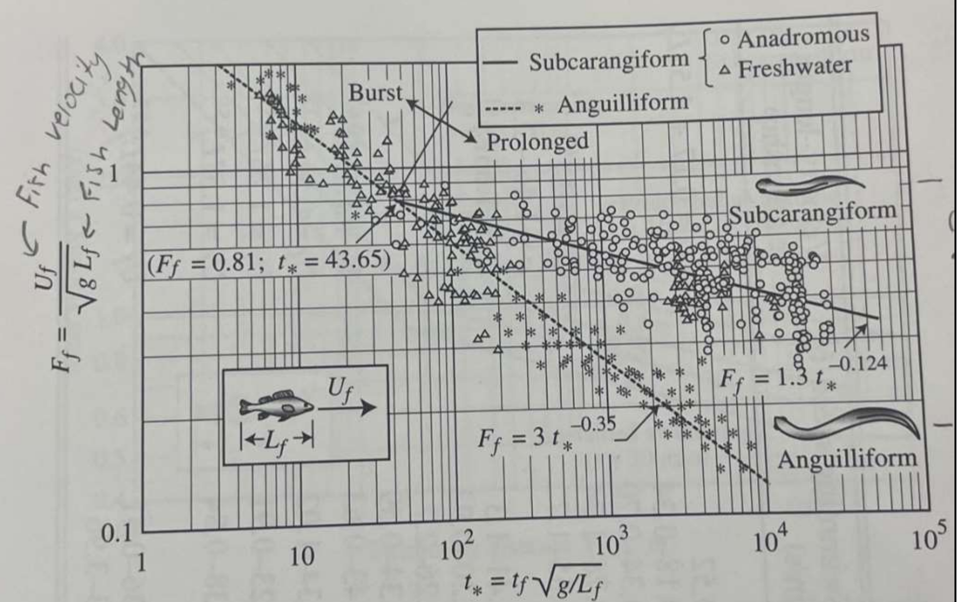


Figure 13.9. Fish endurance characteristics (after Katopodis, 1992)

13.3 Aquatic Environment

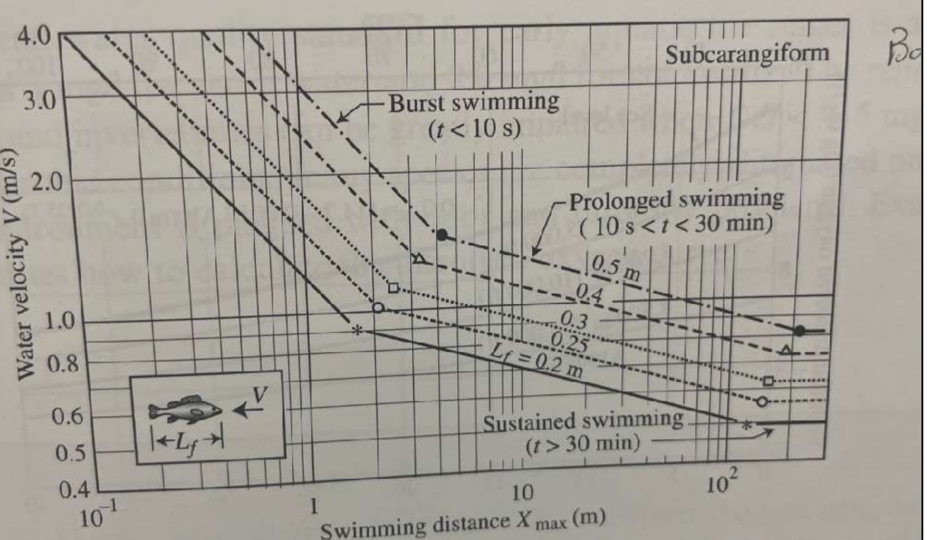


Figure 13.10. Typical swimming distance curve versus fish length (after Katopodis, 1992)

Solution

The swimming velocity in m/s of the fish can be determined using the relationship between velocity and fish length shown in Table 13.2 of the River Mechanics manual:

$$U_f = 0.17 + 1.57L_f$$

Fish endurance, in seconds can be determined by first calculating the Froude number of the fish, then the dimensionless fish endurance characteristics, then the fish endurance, as shown by the equations below.

$$F_f = \frac{U_f}{\sqrt{gL_f}}$$

$$t_* = \left(\frac{F_f}{1.3}\right)^{-8.064}$$

$$t_f = \frac{t_*}{\sqrt{g/L_f}}$$

In general terms, Figure 13.9 from the River Mechanics manual indicates that as fish velocity increases, fish endurance decreases. It also indicates that as fish length increases, fish velocity increases and that although smaller fish are typically slower, they also have greater endurance to swim at their max velocity than adult salmon do. Values of maximum velocity and the corresponding endurance are shown below.

Param.	Adult	Smolt
L_f (m)	0.7	0.15
U_f (m/s)	**1.27**	**0.41**
F_f	0.48	0.33
t_*	2,873	57,070
t_f (s)	**768**	**7,057**

The tables below give an idea of fish endurance and maximum endurance swimming distance at a range of flow velocities. The dimensionless fish Froude number and the maximum endurance swimming distance at each flow velocity are given by the following equations:

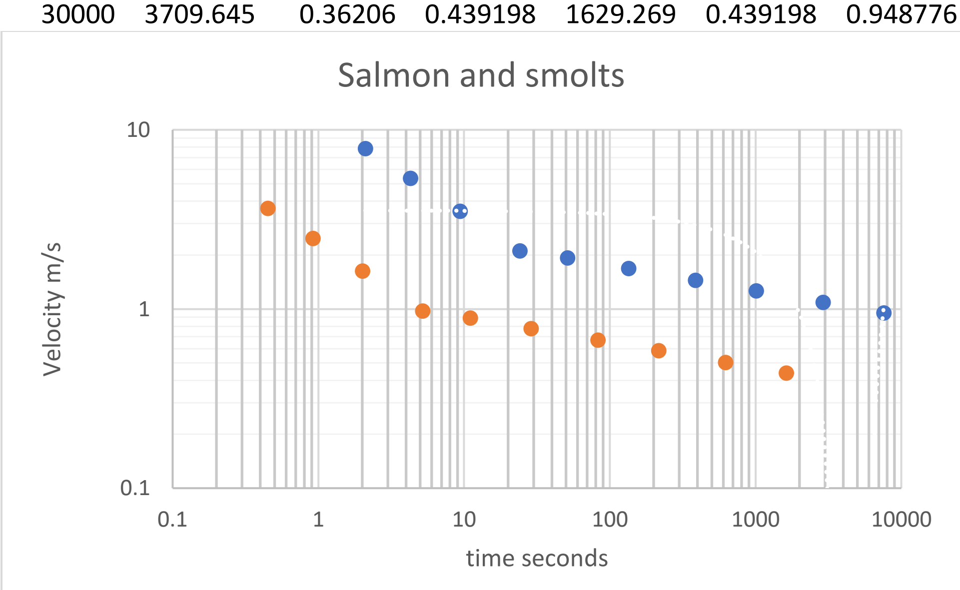
$$F_{Vf} = \frac{V}{\sqrt{gL_f}}$$

L		0.7 Salmon			

t*	t	Ff	Vf	Xmax	Vf
1	0.267125	3	7.861488	2.1	7.861488
3	0.801375	2.042344	5.351954	4.288922	5.351954
10	2.67125	1.340051	3.511598	9.380355	3.511598
43	11.48637	0.80428	2.107613	24.20883	2.107613
100	26.7125	0.734418	1.92454	51.40926	1.92454
300	80.1375	0.640885	1.679437	134.5859	1.679437
1000	267.125	0.552005	1.446528	386.4038	1.446528
3000	801.375	0.481704	1.262304	1011.579	1.262304
10000	2671.25	0.4149	1.087244	2904.299	1.087244
30000	8013.75	0.36206	0.948776	7603.256	0.948776

L		0.15 Smolts				

t*	t	Ff	Vf	Xmax	Vf _ll	Vf _l
1	0.123655	3	3.639162	0.45	3.639162	7.861488
3	0.370965	2.042344	2.477473	0.919055	2.477473	5.351954
10	1.236548	1.340051	1.625554	2.010076	1.625554	3.511598
43	5.317158	0.80428	0.975635	5.187606	0.975635	2.107613
100	12.36548	0.734418	0.890889	11.01627	0.890889	1.92454
300	37.09645	0.640885	0.777428	28.83984	0.777428	1.679437
1000	123.6548	0.552005	0.669612	82.80081	0.669612	1.446528
3000	370.9645	0.481704	0.584333	216.7668	0.584333	1.262304
10000	1236.548	0.4149	0.503296	622.3499	0.503296	1.087244
30000	3709.645	0.36206	0.439198	1629.269	0.439198	0.948776



$$x_{max} \cong 0.4 L_f F_{Vf}^{-7} \; for \; F_{Vf} < 0.65$$

For slow velocities of 0.4 m/s, the endurance of over 2,000 hours for large salmon, as indicated by the table, is unrealistic. However, this table does give a general indication of the time and distance at which adult and smolt salmon can travel at various flow velocities. Note that the flow velocity was capped at the corresponding maximum fish velocity for both the adult and the smolt.

		Adult					
	V (m/s)	F_{Vf}	t_*	t_f (s)	t_f (hr)	X_{max} (m)	X_{max} (km)
	0.4	0.15	31,744,768	8,479,821	2,356	145,018	145.0
	0.5	0.19	5,250,369	1,402,505	390	30,413	30.4
	0.6	0.23	1,206,903	322,394	90	8,488	8.5
	0.7	0.27	348,188	93,010	26	2,885	2.9
	0.8	0.31	118,622	31,687	8.8	1,133	1.1
	0.9	0.34	45,885	12,257	3.4	497	0.5
	1.0	0.38	19,619	5,241	1.5	238	0.2
	1.1	0.42	9,097	2,430	0.7	122	0.1
	1.2	0.46	4,510	1,205	0.33	66	0.1
Max Adult U_f	1.27	0.48	2,855	763	0.21	45	0.04

		Smolt					
	V (m/s)	F_{Vf}	t_*	t_f (s)	t_f (hr)	X_{max} (m)	X_{max} (km)
	0.4	0.33	63,714	7,879	2.2	142	0.1
Max Smolt U_f	0.41	0.34	52,211	6,456	1.8	119	0.1

PROBLEM #5 (10%)– GUEST LECTURE

Write half a page describing what you learned from Dr. Baird's lecture.

Dr. Drew Baird presented a guest lecture discussing river mechanics principles and the United States Bureau of Reclamation (USBR) work along the Rio Grande corridor. This work along the Rio Grande has spanned several decades and has helped to inform several recently published guidance manuals, including Bank Stabilization Design Guidelines, Managing Infrastructure in the Stream Environment, and Guidelines for Evaluating Pipeline Channel Crossing Hazards to Ensure Effective Burial. In his lecture, Dr. Baird uses examples from his work along the Rio Grande to touch on principles discussed in class, including channel migration, scour, sediment transport and supply.

I was particularly interested to learn about the research that the USBR undertook at the Isleta Diversion Dam with the goal of reducing aggradation and increasing sediment transport through the sluiceway. This aggradation at the sluiceway had major implications for maintenance costs. In 2019 alone, the Middle Rio Grande Conservancy District spent