Technical Note

To:	Natural Resources Wales	From:	Envireau Water
Ref:	P19-144 Vivod Licensing \ TN - Application Addendum	Pages:	4 + 2 Figures + 2 Appendices
Re:	Addendum to Licence Application Documents	Date:	09/04/20

1 INTRODUCTION

Envireau Water have submitted licence variation applications on behalf of Vivod Estates to Natural Resources Wales (NRW). These licence variations relate to a domestic abstraction licence (Application No. PAN-007902) and an impoundment licence and HEP abstraction licence (Application No. PAN-007903 & 7904).

NRW have raised concerns with the application in regard to:

1. Reliance on manual intervention to comply with the licence. As flows fluctuate above and below Q95, the proposals required manual adjustment of sluice boards.

2. The methodology and calculations used in the applications to assess weir and sluice flows (i.e. a velocity-area method and a calibrated Manning's model), rather than using British Standards for the weir design.

NRW have requested that more information is provided on the detailed calculations and the weir/sluice offtake arrangements are revised so that there is no manual operation.

To this end and to avoid any further delay, Envireau Water have re-assessed the flows for the weir and sluice offtakes using British Standard calculations for broad crested weirs (taken from BS ISO 3846 : 2008, Hydrometry — Open channel flow measurement using rectangular broad-crested weirs) and standard equations for sluices. These equations have been provided in Appendix A.

On this basis, this technical note sets out the updated proposals and amendments to the continuation sheet provided within the original impoundment variation application.

2 AMENDMENTS TO “FORM WRE SECTION 2 – IMPOUNDMENT DETAILS”

Based on the standard equations, the proposed impoundment and sluice offtakes have been adjusted to ensure that there is no manual adjustment of sluice boards. These adjustments to the impoundment are provided in Figures 4.r1 and 5.r1 (revisions to Figures 4 and 5 provided in the original application).

3 AMENDMENTS TO “FORM WRE SECTION 3 – IMPOUNDMENT DESCRIPTION”

Pg. 3 of the continuation sheet for the original impoundment variation application set out a description of the impoundment. This description has been altered to the following:

> “The change to the impoundment structure is not expected to cause a change in the wetted perimeter or submerged area.
>
> The ponded area created by the existing impoundment structure is unlined and this will not be altered.
>
> The impoundment and the offtakes will comprise of broad crested weirs and sluice boards. The crest level of the wide weir and small impoundment weir are 290.28mAOD and 290.1mAOD respectively. This is taken from a bed level of 290mAOD.
>
> The estimation of flows at the existing impoundment structure and sluice offtakes has been undertaken using equations taken from the British Standard for broad crested weirs (BS ISO 3846 : 2008, Hydrometry — Open channel flow measurement using rectangular broad-crested weirs) and standard calculations for sluices. In order to replicate the sluice offtakes for the domestic and HEP abstraction, the broadcrest weir calculation has been used up to the point where the sluice boards begin to restrict flow, thereafter, the sluice equation is used. The detail of these calculations is provided in Appendix B.
>
> Table 2 shows the calculated simultaneous flow rate at the domestic supply offtake, the HEP offtake and the watercourse flows for a range of watercourse Q values for the proposed impoundment structure. A requirement of the impoundment structure under the HEP abstraction licence WA/067/0005/002 is no more than 70% of the flow within Vivod Brook may be abstracted when flows are above 7 l/s. Flows must not be taken below 7 l/s or above 42 l/s. The percentage of flow abstracted above 7 l/s is also presented in Table 2.
>
> A further requirement is that there needs to be sufficient flow in the domestic offtake to provide the domestic supply. The minimum flow requirement for the domestic supply has been calculated as circa. 1.8 l/s.
>
> To achieve the above, it is proposed that:
>
> - The domestic supply offtake has the same invert level as the small impoundment weir. The sluice board is set with a gap of 20mm to restrict flows. This will provide 1.9 l/s flow for a depth of 20mm of water for Q99.9 flows. This will provide water security for the domestic supply.
> - The HEP offtake invert is set 5cm above the invert of the small impoundment weir so that abstraction for the HEP can only occur when flows are above the 7 l/s HOF condition.
> - The HEP offtake sluice board gap is set to 95mm to provide a high flow restriction.
> - The combined high flow restriction when the small impoundment weir reaches its maximum capacity (i.e. a 18cm weir water depth or c. 70 l/s or c. Q8) for the domestic and HEP offtakes is c. 41 l/s.
> - Once the capacity of the small impoundment weir has been reached, the watercourse will spill over the wider impoundment weir. The maximum capacity of the wide weir is estimated as 1.4 cumecs.

Table 2 Estimated flows for the proposed impoundment structure and abstraction offtake.

Q value (Annual)	Upstream Watercourse Flow (l/s)	Water depth at small impoundment weir (cm)	Water depth at HEP sluice (cm)	Flow over small impoundment weir (l/s)	Flow over wide weir (l/s)	Total flow in watercourse downstream of weir (l/s)	Flow in domestic offtake (l/s)	Flow in HEP offtake (l/s)	Total Flow in offtake channel (l/s)	% of flow abstracted above 7 l/s
Q8	110.9	18	13.5	70.32	0	70.3	7.60	32.96	40.6	39%
Q9	106.4	17.5	13	66.85	0	66.8	7.49	32.08	39.6	40%
Q10	102.0	17	12.5	63.46	0	63.5	7.37	31.15	38.5	41%
Q10.5	97.6	16.5	12	60.16	0	60.2	7.25	30.16	37.4	41%
Q11.5	93.2	16	11.5	56.95	0	57.0	7.13	29.11	36.2	42%
Q13	88.8	15.5	11	53.83	0	53.8	7.00	27.95	35.0	43%
Q14	84.3	15	10.5	50.80	0	50.8	6.88	26.60	33.5	43%
Q15	79.5	14.5	10	47.95	0	47.9	6.75	24.83	31.6	44%
Q16	76.0	14	9.5	45.17	0	45.2	6.62	24.23	30.9	45%
Q18	71.0	13.5	9	42.48	0	42.5	6.49	22.06	28.5	45%
Q20	66.2	13	8.5	39.86	0	39.9	6.35	19.99	26.3	44%
Q23	60.5	12.5	8	37.32	0	37.3	6.21	17.01	23.2	43%
Q25.5	56.3	12	7.5	34.85	0	34.9	6.07	15.36	21.4	43%
Q27	52.2	11.5	7	32.50	0	32.5	5.93	13.77	19.7	44%
Q30.5	48.3	11	6.5	30.22	0	30.2	5.78	12.26	18.0	44%
Q33	44.5	10.5	6	28.02	0	28.0	5.64	10.82	16.5	44%
Q36	40.8	10	5.5	25.88	0	25.9	5.48	9.44	14.9	44%
Q40	37.3	9.5	5	23.82	0	23.8	5.33	8.14	13.5	44%
Q43	33.9	9	4.5	21.83	0	21.8	5.16	6.91	12.1	45%
Q47	30.7	8.5	4	19.93	0	19.9	5.00	5.76	10.8	45%
Q51	27.6	8	3.5	18.10	0	18.1	4.83	4.69	9.5	46%
Q56	24.7	7.5	3	16.34	0	16.3	4.65	3.71	8.4	47%
Q61	21.9	7	2.5	14.65	0	14.7	4.47	2.80	7.3	49%
Q66	19.3	6.5	2	13.04	0	13.0	4.28	2.00	6.3	51%
Q70	16.9	6	1.5	11.50	0	11.5	4.09	1.29	5.4	54%
Q75	14.6	5.5	1	10.04	0	10.0	3.88	0.70	4.6	60%
Q79	12.6	5	0.5	8.65	0	8.7	3.67	0.25	3.9	70%
Q84	10.8	4.5	0	7.35	0	7.4	3.44	0.00	3.4	
Q90	9.3	4	0	6.13	0	6.1	3.20	0.00	3.2	
Q94	7.9	3.5	0	4.99	0	5.0	2.94	0.00	2.9	
Q97.5	6.6	3	0	3.94	0	3.9	2.66	0.00	2.7	
Q98.5	5.3	2.5	0	2.98	0	3.0	2.32	0.00	2.3	
Q99.9	4.0	2	0	2.12	0	2.1	1.91	0.00	1.9	
	2.6	1.5	0	1.37	0	1.4	1.24	0.00	1.2	
	1.4	1	0	0.74	0	0.7	0.67	0.00	0.7	
	0.5	0.5	0	0.26	0	0.3	0.24	0.00	0.2	

Table 2 shows the proposed structure meets the abstraction licence requirements set out in the abstraction licence variation applications."

4 SUMMARY

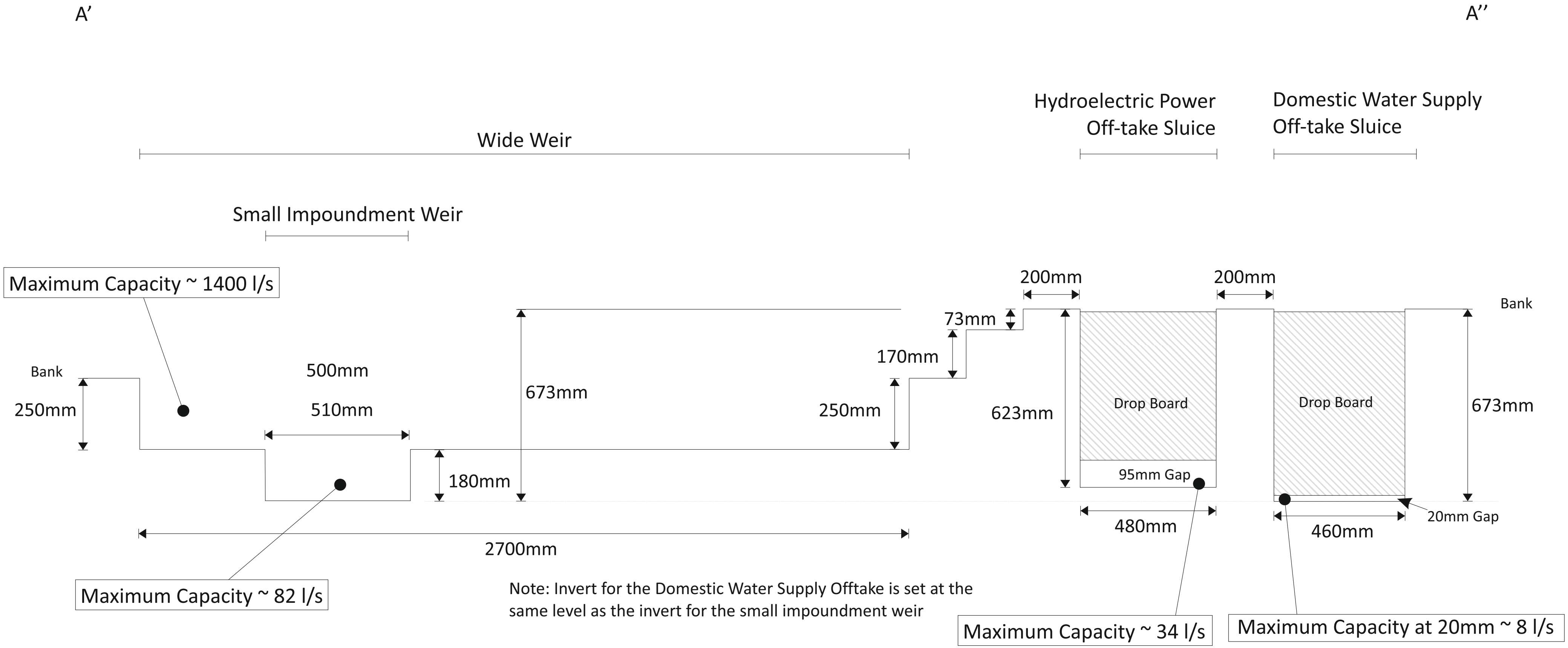
NRW have raised concerns regarding the flow calculations supporting the domestic abstraction, impoundment and HEP abstraction licence variations, and also the requirement for the manual adjustment of sluice boards for the abstraction offtake.

New calculations have been undertaken using standard equations for broad crested weirs and sluices. This has led to alterations in the impoundment structure to ensure compliance with the proposed abstraction rates.

The alterations also ensure that there will be no manual adjustment of the sluice gates during abstraction.

Envireau Water
09/04/20

FIGURES



Scale 1 : 20 at A4

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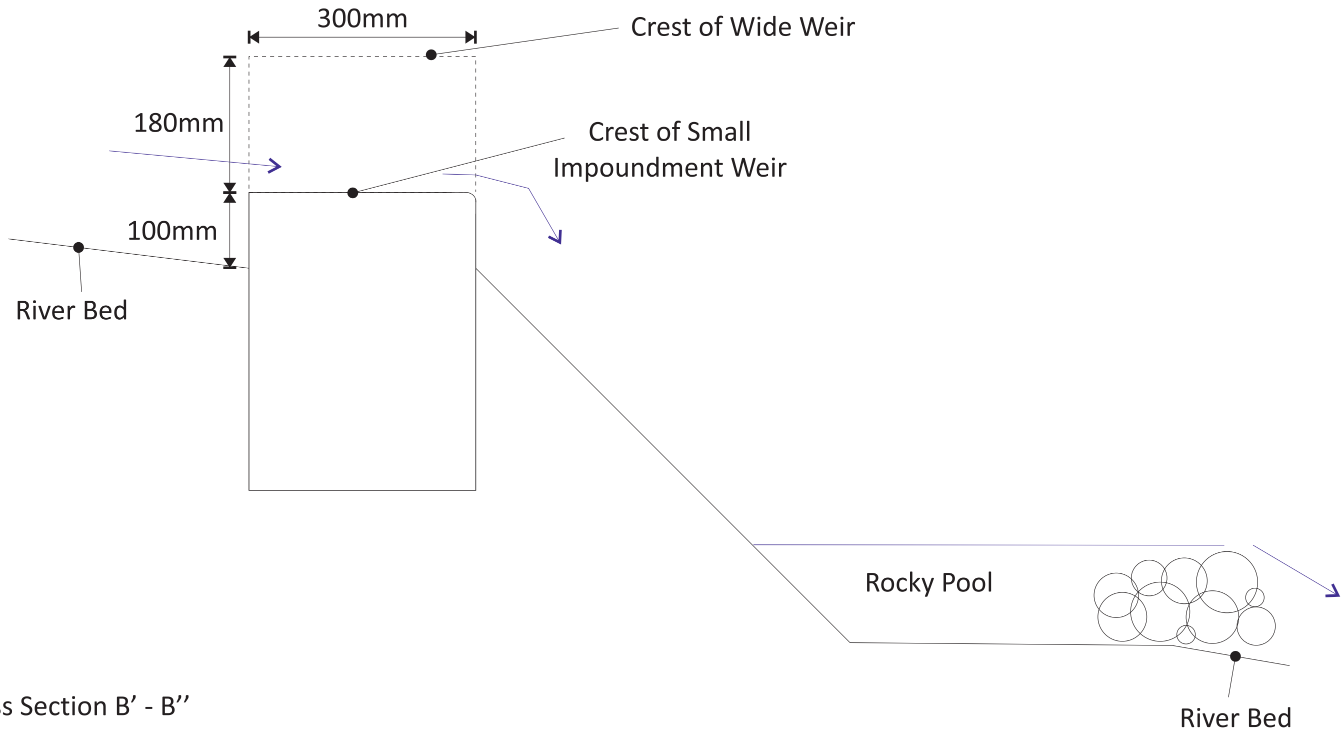
Ref: P19-144 - Vivod Licensing \ FIG 4 r1 Impoundment Date: 08/04/2020	**Vivod Estates**
Figure 4 r1	Cross Section of Proposed Alterations to the Existing Impoundment Structure



Cross Section B' - B''
Scale 1:10 at A4

Cross Section C' - C''
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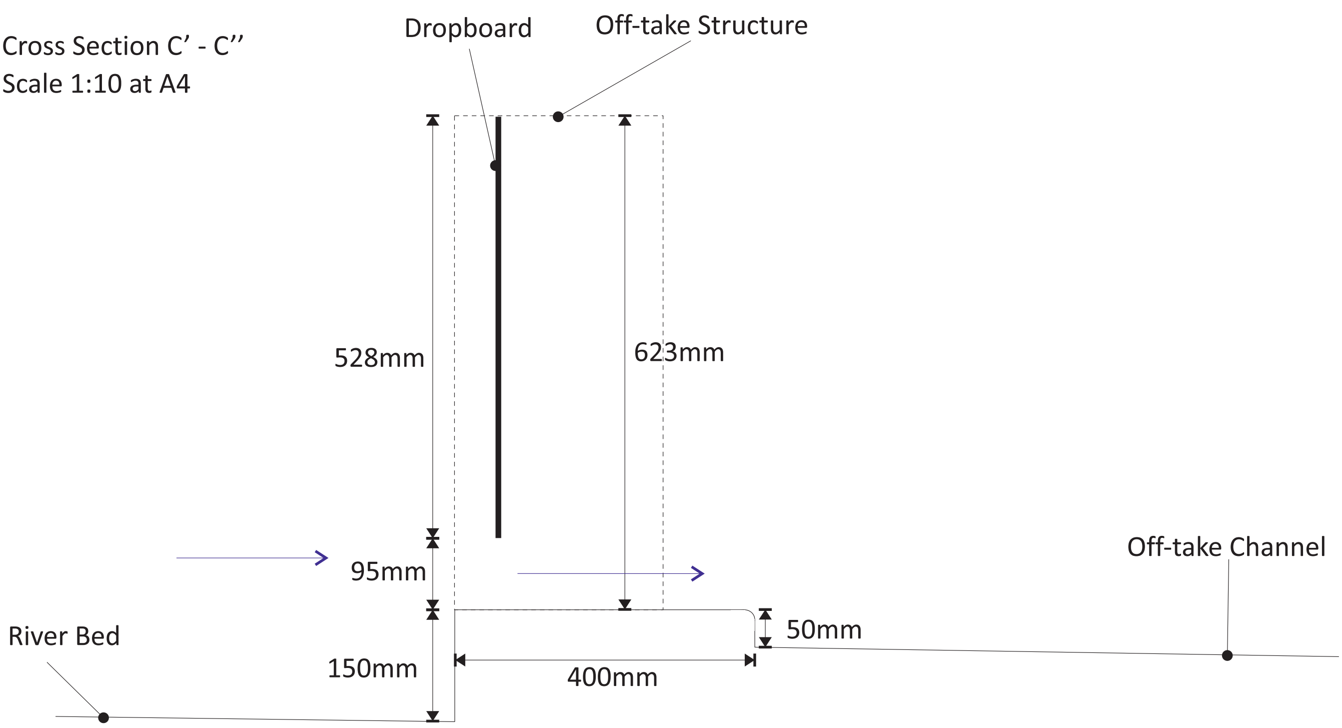

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Ref: P19-144 - Vivod Licensing \ FIG 5 r1 Impoundment Date: 08/04/2020	**Vivod Estates**
Figure 5 r1	Cross Section of Impoundment Structure & HEP Off-take Structure

APPENDIX A
EQUATIONS USED IN FLOW CALCULATIONS

Equation for broad crested weir (taken from BS ISO 3846 : 2008, Hydrometry — Open channel flow measurement using rectangular broad-crested weirs):

$$Q = \left(\frac{2}{3}\right)^{3/2} g^{1/2}\, b\, C\, h_1^{3/2}$$

where

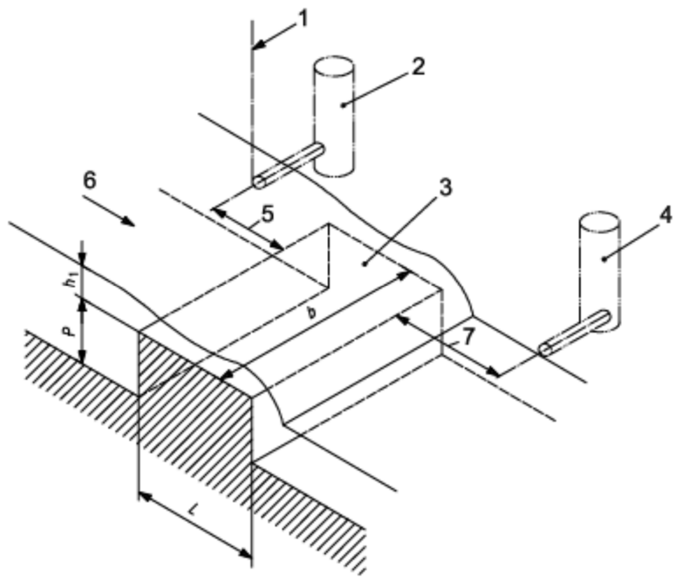
Q is the volumetric rate of flow;

g is the acceleration due to gravity;

b is the width of the weir perpendicular to the direction of flow;

C is the gauged head discharge coefficient;

h_1 is the upstream gauged head related to the crest elevation.



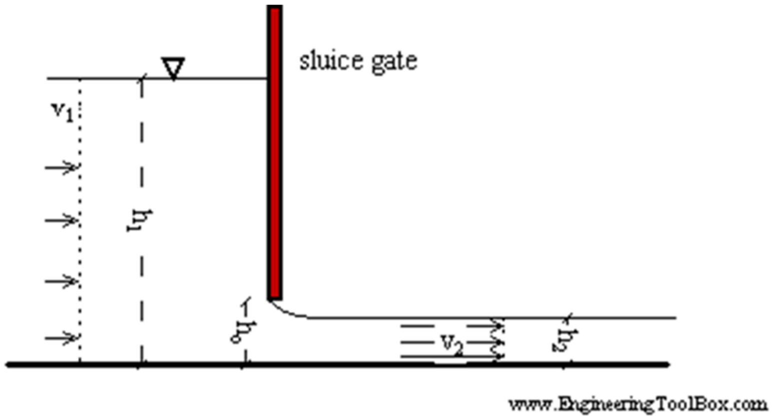
h_1/p	C for the following values of h_1/L																	
	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8
0,1	0.85	0,850	0,850	0,861	0,870	0,885	0,893	0,925	0,948	0,971	0,993	1,016	1,039	1,062	1,085	1,106	1,130	1,148
0,2	0.855	0,855	0,855	0,864	0,874	0,888	0,907	0,930	0,954	0,977	1,001	1,026	1,050	1,074	1,096	1,120	1,142	1,159
0,3	0.864	0.864	0,864	0,868	0,879	0,894	0,913	0,936	0,961	0,986	1,011	1,037	1,061	1,085	1,110	1,132	1,152	1,169
0,4	0.873	0,873	0,873	0,874	0,885	0,901	0,920	0,945	0,969	0,995	1,021	1,047	1,072	1,097	1,122	1,144	1,163	1,180
0,5	0.882	0,882	0,882	0,883	0,894	0,909	0,929	0,954	0,978	1,005	1,032	1,057	1,083	1,109	1,133	1,154	1,173	1,188
0,6	0.892	0,892	0,892	0.894	0,904	0,920	0,941	0,964	0,990	1,016	1,043	1,067	1,094	1,120	1,143	1,164	1,182	1,196
0,7	0.901	0,901	0,901	0,906	0,916	0,932	0,952	0,975	1,000	1,026	1,052	1,077	1,104	1,129	1,152	1,171	1,188	1,203
0,8	0.911	0,911	0,912	0,916	0,926	0,942	0,962	0,985	1,010	1,036	1,062	1,086	1,112	1,136	1,158	1,176	1,194	1,209
0,9	0,921	0,921	0,922	0,926	0,936	0.952	0,972	0,996	1,020	1,046	1,072	1,096	1,120	1,143	1,163	1,181	1,199	1,214
1,0	0,929	0,929	0,931	0,936	0,946	0,962	0,982	1,006	1,031	1,056	1,081	1,106	1,128	1,150	1,169	1,187	1,204	1,220
1,1	0,935	0,937	0,940	0,946	0,956	0,972	0,993	1,017	1,042	1,066	1,092	1,115	1,138	1,159	1,117	1,195	1,212	1,228
1,2	0,941	0,944	0,949	0,956	0,966	0,982	1,004	1.028	1,053	1,077	1,103	1,126	1,148	1,168	1,186	1,204	1,222	1,237
1,3	0,946	0,951	0,957	0,966	0,977	0,993	1,016	1,040	1,063	1,089	1,114	1,136	1,158	1,178	1,196	1,214	1,232	1,250
1,4	0,953	0,959	0,967	0,975	0,986	1,005	1,028	1,050	1,075	1,101	1,124	1,147	1,168	1,187	1,206	1,224	1,244	1,266
1,5	0,961	0,968	0,975	0,984	0,997	1,018	1,040	1,061	1,086	1.111	1,134	1,156	1,176	1,196	1,215	1,235	1,258	1,277
1,6	0,972	0,978	0,985	0,994	1,010	1,030	1,050	1,073	1,096	1,119	1,142	1,164	1.184	1,204	1,224	1,245	1,268	1,289

Equation for sluice gate:

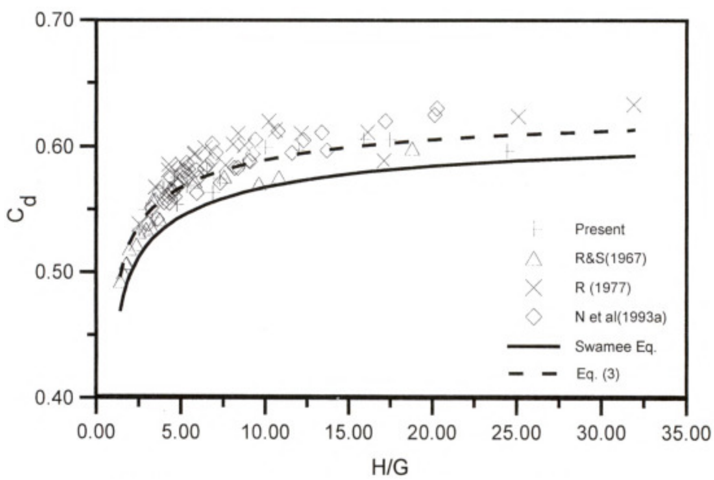
$Q = C_d h_2 b [2 g (h_1 - h_2) / (1 - (h_2 / h_1))]^{1/2}$

where

Q is the volumetric rate of flow
g is the acceleration due to gravity
b is the width of sluice opening perpendicular to the direction of flow
C_d if the coefficient of discharge
h_1 is the upstream head related to the crest elevation
h_2 is the downstream head related to the crest elevation



$C_d = 0.63 ((H-G) / (H+15G))^{0.0649}$



where

H is the upstream flow depth above the crest elevation
G is the sluice gate opening

(*after* Abdualaziz A.Alhamid : Coefficient of Discharge for Free Flow Sluice Gates. Journal of King Saud University - Engineering Sciences. Volume 11, Issue 1, 1999, Pages 33-47. https://www.sciencedirect.com/science/article/pii/S1018363918309899)

APPENDIX B
DETAILS OF FLOW CALCULATIONS

Flow calculations:

For Domestic
(Composite of broadcrest and sluice)
G = 0.02 m
B = 0.46 m
Crest base = 0 m above weir

Upstream watercourse level	H/G=	Cd (sluice)=	Cd (broad)=	h_1 =	h_2 =	Q (m^3/s)	Q (l/s)
0.18	9	0.587		0.18	0.015	0.0076	7.60
0.175	8.75	0.586		0.175	0.015	0.0075	7.49
0.17	8.5	0.585		0.17	0.015	0.0074	7.37
0.165	8.25	0.584		0.165	0.015	0.0072	7.25
0.16	8	0.583		0.16	0.015	0.0071	7.13
0.155	7.75	0.582		0.155	0.015	0.0070	7.00
0.15	7.5	0.581		0.15	0.015	0.0069	6.88
0.145	7.25	0.580		0.145	0.015	0.0067	6.75
0.14	7	0.579		0.14	0.015	0.0066	6.62
0.135	6.75	0.578		0.135	0.015	0.0065	6.49
0.13	6.5	0.577		0.13	0.015	0.0064	6.35
0.125	6.25	0.575		0.125	0.015	0.0062	6.21
0.12	6	0.574		0.12	0.015	0.0061	6.07
0.115	5.75	0.573		0.115	0.015	0.0059	5.93
0.11	5.5	0.571		0.11	0.015	0.0058	5.78
0.105	5.25	0.569		0.105	0.015	0.0056	5.64
0.1	5	0.568		0.1	0.015	0.0055	5.48
0.095	4.75	0.566		0.095	0.015	0.0053	5.33
0.09	4.5	0.564		0.09	0.015	0.0052	5.16
0.085	4.25	0.561		0.085	0.015	0.0050	5.00
0.08	4	0.559		0.08	0.015	0.0048	4.83
0.075	3.75	0.556		0.075	0.015	0.0047	4.65
0.07	3.5	0.553		0.07	0.015	0.0045	4.47
0.065	3.25	0.550		0.065	0.015	0.0043	4.28
0.06	3	0.546		0.06	0.015	0.0041	4.09
0.055	2.75	0.542		0.055	0.015	0.0039	3.88
0.05	2.5	0.537		0.05	0.015	0.0037	3.67
0.045	2.25	0.531		0.045	0.015	0.0034	3.44
0.04	2	0.524		0.04	0.015	0.0032	3.20
0.035	1.75	0.515		0.035	0.015	0.0029	2.94
0.03	1.5	0.502		0.03	0.015	0.0027	2.66
0.025	1.25	0.480		0.025	0.015	0.0023	2.32
0.02	1	0	0.855	0.02		0.0019	1.91
0.015	0.75	#NUM!	0.853	0.015		0.0012	1.24
0.01	0.5	#NUM!	0.850	0.01		0.0007	0.67
0.005	0.25	#NUM!	0.848	0.005		0.0002	0.24
0	0	#NUM!					

For broadcrest weir
C= 0.932 (average)
B = 0.51 m

Upstream watercourse level	Cd (broad)=	h =	Q (m^3/s)	Q (l/s)
0.18	1.050	0.18	0.0703	70.32
0.175	1.041	0.175	0.0668	66.85
0.17	1.032	0.17	0.0635	63.46
0.165	1.024	0.165	0.0602	60.16
0.16	1.015	0.16	0.0570	56.95
0.155	1.006	0.155	0.0538	53.83
0.15	0.997	0.15	0.0508	50.80
0.145	0.990	0.145	0.0479	47.95
0.14	0.983	0.14	0.0452	45.17
0.135	0.977	0.135	0.0425	42.48
0.13	0.970	0.13	0.0399	39.86
0.125	0.963	0.125	0.0373	37.32
0.12	0.956	0.12	0.0349	34.85
0.115	0.950	0.115	0.0325	32.50
0.11	0.945	0.11	0.0302	30.22
0.105	0.939	0.105	0.0280	28.02
0.1	0.933	0.1	0.0259	25.88
0.095	0.928	0.095	0.0238	23.82
0.09	0.922	0.09	0.0218	21.83
0.085	0.917	0.085	0.0199	19.93
0.08	0.912	0.08	0.0181	18.10
0.075	0.907	0.075	0.0163	16.34
0.07	0.902	0.07	0.0147	14.65
0.065	0.897	0.065	0.0130	13.04
0.06	0.892	0.06	0.0115	11.50
0.055	0.887	0.055	0.0100	10.04
0.05	0.883	0.05	0.0087	8.65
0.045	0.878	0.045	0.0074	7.35
0.04	0.873	0.04	0.0061	6.13
0.035	0.869	0.035	0.0050	4.99
0.03	0.864	0.03	0.0039	3.94
0.025	0.859	0.025	0.0030	2.98
0.02	0.854	0.02	0.0021	2.12
0.015	0.850	0.015	0.0014	1.37
0.01	0.845	0.01	0.0007	0.74
0.005	0.840	0.005	0.0003	0.26

For HEP
(Composite of broadcrest and sluice)
G = 0.095 m
B = 0.48 m
Crest base = 0.05 m above weir

Upstream watercourse level	H/G=	Cd (sluice)=	Cd (broad)=	h_1 =	h_2 =	Q (m^3/s)	Q (l/s)
0.18	1.42	0.497		0.135	0.085	0.0330	32.96
0.175	1.37	0.493		0.13	0.085	0.0321	32.08
0.17	1.32	0.488		0.125	0.085	0.0311	31.15
0.165	1.26	0.482		0.12	0.085	0.0302	30.16
0.16	1.21	0.475		0.115	0.085	0.0291	29.11
0.155	1.16	0.467		0.11	0.085	0.0279	27.95
0.15	1.11	0.455		0.105	0.085	0.0266	26.60
0.145	1.05	0.435		0.1	0.085	0.0248	24.83
0.14	1.00	#NUM!	1.003	0.095		0.0242	24.23
0.135	0.95	#NUM!	0.990	0.09		0.0221	22.06
0.13	0.89	#NUM!	0.977	0.085		0.0200	19.99
0.125	0.84	#NUM!	0.911	0.08		0.0170	17.01
0.12	0.79	#NUM!	0.906	0.075		0.0154	15.36
0.115	0.74	#NUM!	0.901	0.07		0.0138	13.77
0.11	0.68	#NUM!	0.897	0.065		0.0123	12.26
0.105	0.63	#NUM!	0.892	0.06		0.0108	10.82
0.1	0.58	#NUM!	0.887	0.055		0.0094	9.44
0.095	0.53	#NUM!	0.882	0.05		0.0081	8.14
0.09	0.47	#NUM!	0.878	0.045		0.0069	6.91
0.085	0.42	#NUM!	0.873	0.04		0.0058	5.76
0.08	0.37	#NUM!	0.869	0.035		0.0047	4.69
0.075	0.32	#NUM!	0.864	0.03		0.0037	3.71
0.07	0.26	#NUM!	0.860	0.025		0.0028	2.80
0.065	0.21	#NUM!	0.855	0.02		0.0020	2.00
0.06	0.16	#NUM!	0.853	0.015		0.0013	1.29
0.055	0.11	#NUM!	0.850	0.01		0.0007	0.70
0.05	0.05	#NUM!	0.848	0.005		0.0002	0.25