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CALIBRATION OF SEWER WEIRS FOR THE CITY OF TORONTO

by

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Hydraulics Research Division
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HYDRAULICS RESEARCH DIVISION

Technical Note

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AUTHOR(S): J. Marsalek and J. Dalton

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CALIBRATION OF SEWER WEIRS FOR THE CITY OF TORONTO

1. Terms of Reference

The Department of Public Works of the City of Toronto has decided to install two flow measuring weirs as a part of their ongoing drainage studies. To improve the measuring accuracy of these non-standard weirs, the Hydraulics Research Division was requested to calibrate both weirs by means of scale models.

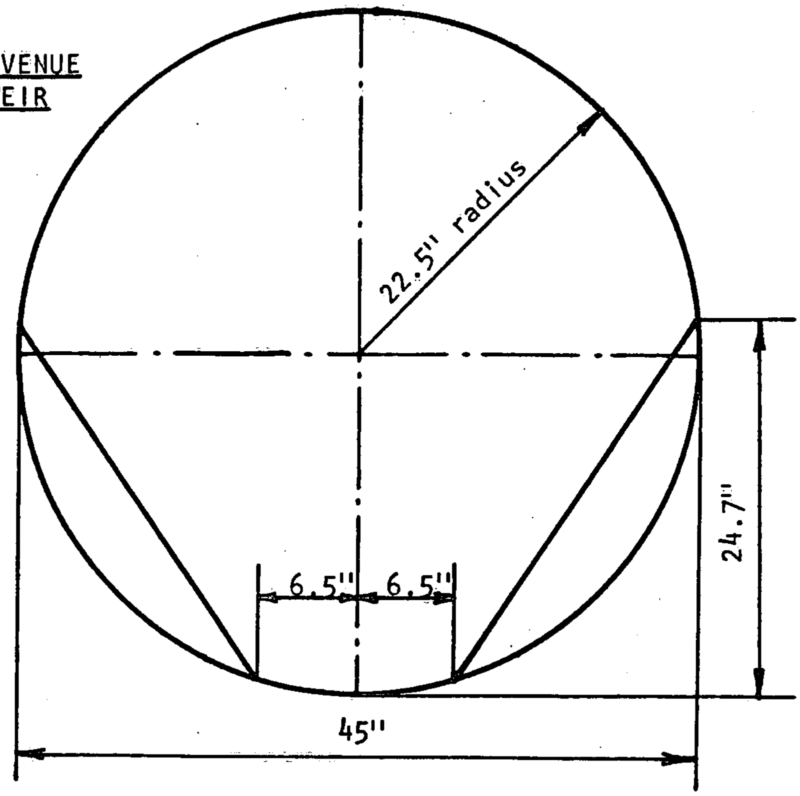
The configurations of both weirs are shown in Figure 1, additional information appears below.

	Location	
Weir Shape	Jones Avenue Vertical Slot of Varying Width	Castlewood Avenue Vertical Slot of Varying Width
Location of the head sensor (in the pipe)	13 ft upstream	12.20 ft upstream
Sewer pipe size and material	48" concrete pipe	45" brick pipe
Estimated pipe roughness (Manning's n)	0.013	0.013-0.015
Upstream sewer slope	1:216	1:287
Estimated pipe capacity	98 cfs	71 cfs (n = 0.013)

2. Model Similarity

Considering the sizes and hydraulic capacities of both installations, it was impossible to calibrate the weirs in the prototype scale and, consequently, scale models of both installations had to be used. Since the forces controlling the flow through the installations are those of gravity, the models were constructed according to the Froude similarity. This condition implies that the Froude numbers in the prototype and the model are identical. Consequently, the various model scales are defined as follows:

CASTLEWOOD AVENUE
WEIR



JONES AVENUE
WEIR

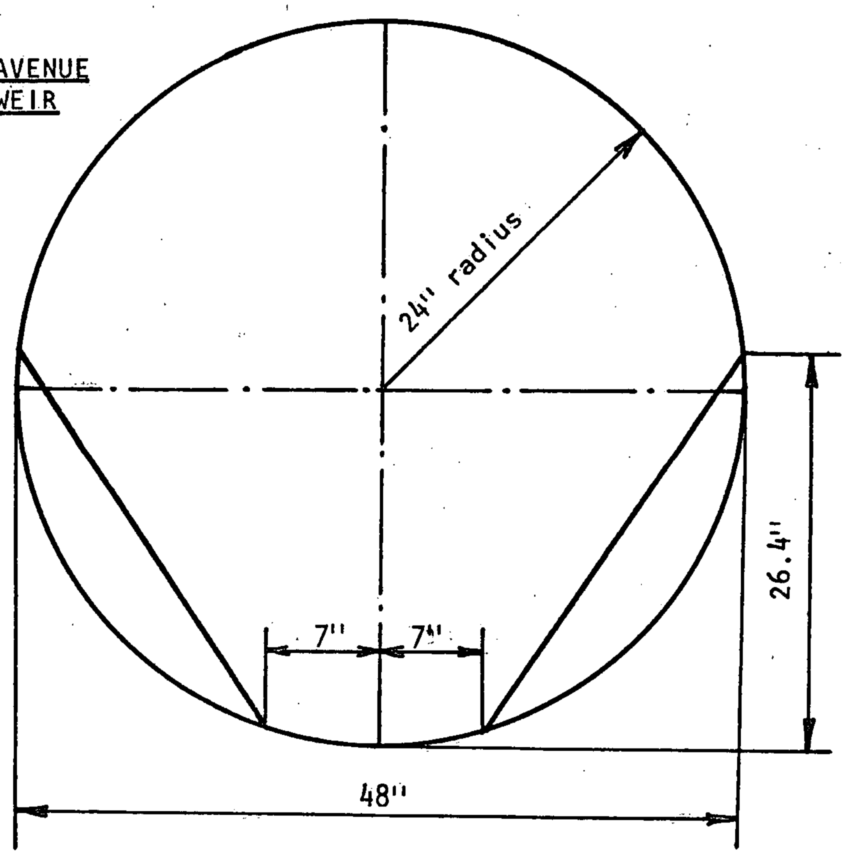


Fig.1. CASTLEWOOD AND JONES AVENUE WEIRS CONFIGURATIONS

Length scale $\lambda_\ell = \frac{\ell_p}{\ell_m}$

Velocity scale $\lambda_V = \frac{V_p}{V_m} = \lambda_\ell^{1/2}$

Flow rate scale $\lambda_Q = \frac{Q_p}{Q_m} = \lambda_\ell^{5/2}$

where ℓ is a characteristic dimension (e.g. sewer pipe diameter), V is the flow velocity, Q is the flow rate, and p and m are the subscripts referring to the prototype and model, respectively.

The actual selection of the model scale is governed by practical considerations as well as by the necessity to truly reproduce the prototype flow conditions in the model. In this case, an available plastic pipe (D_m = 17") was found suitable for modelling the actual sewer pipe and was used in the tests described here. Using the above scale relationships, the following scales were derived for the installations tested:

	Installation	
	Jones Avenue	Castlewood Avenue
Model (length) scale	(17:48) 1:2.82	(17:45) 1:2.65
Velocity scale	1:1.68	1:1.63
Flow rate scale	1:13.40	1:11.40

The rating curves of weirs seem to be generally affected by the approach velocity. When calculating the approach velocities in the model pipe, they were found somewhat higher than the scaled-down prototype velocities. This was caused by the fact that the model pipe roughness (n = 0.010) was smaller than the scaled down prototype roughness. To simulate properly the approach velocity, the model slope was slightly reduced. Since the pipe slope was found to affect the weir rating curves only slightly, it is believed that the slope distortion employed has not unduly affected the model similarity.

The terms of reference called for the calibration of two geometrically similar weir installations. In fact, the Castlewood Avenue weir was designed as a scale model (1:1.07) of the Jones Avenue weir. Consequently, only one model weir was tested for two different pipe slopes to account for the differences in sewer characteristics of both installations. The first rating curve was produced for the Jones Avenue weir and corresponded to a concrete sewer pipe (n = 0.013) on a slope of 1:216. The second curve was produced for the Castlewood Avenue weir and corresponded to a brick sewer pipe (n = 0.015) on a slope of 1:287. For other values of the slope and roughness, one could interpolate between the two rating curves presented.

3. Experimental Apparatus

A scale model of the prototype installations was built and installed in the IM flume of the Hydraulics Research Division. The sewer pipe was reproduced by means of a plastic pipe (D_m = 17", length = 24 ft). At the upstream end, a special transition section was attached to the pipe to reduce inlet losses. The water level at the outlet end of the model was controlled to avoid a possible drawdown.

The model weir plates were made of aluminum and installed about 18 ft downstream from the pipe inlet.

To measure the weir head, a point gauge and a piezometer tap were installed about 4.6 ft (a model dimension) upstream of the weir. In both cases, the depth of flow could be read to 0.1 mm.

Model flow rates were measured by means of a calibrated V-notch weir for flows of up to 2.5 cfs and, for higher flows, by means of a volumetric tank. In both cases, a measuring accuracy of ±2% was achieved.

4. Laboratory Procedure

For a selected flow rate, the flow in the model was allowed to stabilize for 10 to 20 minutes. After this period, the weir head was measured by means of the piezometer tap connected to a stilling well, checked against the reading of a point gauge, and recorded. Subsequently, the flow rate was measured either by means of the V-notch weir, or by using the volumetric tank. The flow rates were increased in a large number of small steps until the flow range desired was fully covered. After the first series of tests, the pipe slope was altered to reproduce the conditions at the Castlewood installation and the whole procedure was repeated. In this second experimental series, only a limited number (14) of points was measured, since the general shape of the rating curve had been well defined in the first series.

A full pipe flow could not be achieved in the tests, because the pipe had several openings along the pipe crown. Extrapolation is recommended beyond the range of flows measured.

5. Results and Discussion

All the valid measurements are listed in Table I and plotted in Figure 2. The rating curves for both weir installations appear to be well defined and are in general agreement with the results obtained for other weirs of a similar nature.

A good flow measuring accuracy (±5%) can be expected at both field installations. One possible source of error was brought to the attention of the client. For flow depths above 0.5 D of the sewer pipe, the water level at the

TABLE 1A. Rating Curve of the Jones Avenue Weir

Run No.	Model (1:2.82)		Prototype			
	h_m(m)	Q_m (m^3/s)	h_p (m)	Q_p (m^3/s)	h_p(ft)	Q_p(cfs)
1	.0209	.00097	.059	.0130	.193	.459
2	.0228	.00112	.064	.0150	.211	.530
3	.0246	.00122	.069	.0163	.228	.577
4	.0392	.00238	.111	.0319	.363	1.126
5	.0710	.00606	.200	.0812	.657	2.867
6	.0868	.00840	.245	.1125	.804	3.974
7	.1151	.01449	.325	.1941	1.066	6.855
8	.1194	.01600	.337	.2143	1.105	7.569
9	.1374	.02009	.388	.2691	1.272	9.504
10	.1608	.02723	.454	.3648	1.489	12.882
11	.1796	.03448	.507	.4619	1.663	16.312
12	.2008	.04257	.567	.5703	1.859	20.139
13	.2351	.06008	.664	.8048	2.176	28.423
14	.2481	.06967	.701	.9333	2.297	32.959
15	.2585	.07410	.730	.9927	2.393	35.055
16	.2600	.07772	.734	1.0412	2.407	36.768
17	.2830	.08900	.799	1.1923	2.620	42.104
18	.3048	.10880	.861	1.4575	2.822	51.471
19	.3249	.12540	.917	1.6799	3.008	59.324
20	.3649	.16330	1.030	2.1876	3.378	77.254
21	.3950	.17560	1.115	2.3524	3.657	83.072

h_m = the head above the model weir

Q_m = the model weir discharge

h = the head above the prototype weir (derived from the model)

Q_m = the prototype weir discharge (derived from the model)

TABLE IB. Rating Curve of the Castlewood Avenue Weir

Run No.	Model (1:2.65)		Prototype			
	h_m (m)	Q_m (m^3/s)	h_p (m)	Q_p (m^3/s)	h_p (ft)	Q_p (cfs)
1	.0303	.00117	.080	.01334	.263	.471
2	.0658	.00438	.174	.04993	.571	1.763
3	.0778	.00620	.206	.07068	.675	2.496
4	.0928	.00877	.246	.09998	.805	3.531
5	.1348	.01820	.357	.20748	1.170	7.327
6	.1624	.02582	.430	.29435	1.409	10.395
7	.1918	.03662	.508	.41747	1.665	14.743
8	.2173	.04773	.575	.54413	1.886	19.216
9	.2458	.06300	.651	.71821	2.133	25.363
10	.2608	.07263	.690	.82799	2.263	29.240
11	.2778	.08530	.735	.97243	2.411	34.341
12	.3298	.11710	.873	1.33495	2.862	47.143
13	.3508	.13315	.929	1.51792	3.045	53.605
14	.3880	.15790	1.027	1.80008	3.367	63.569

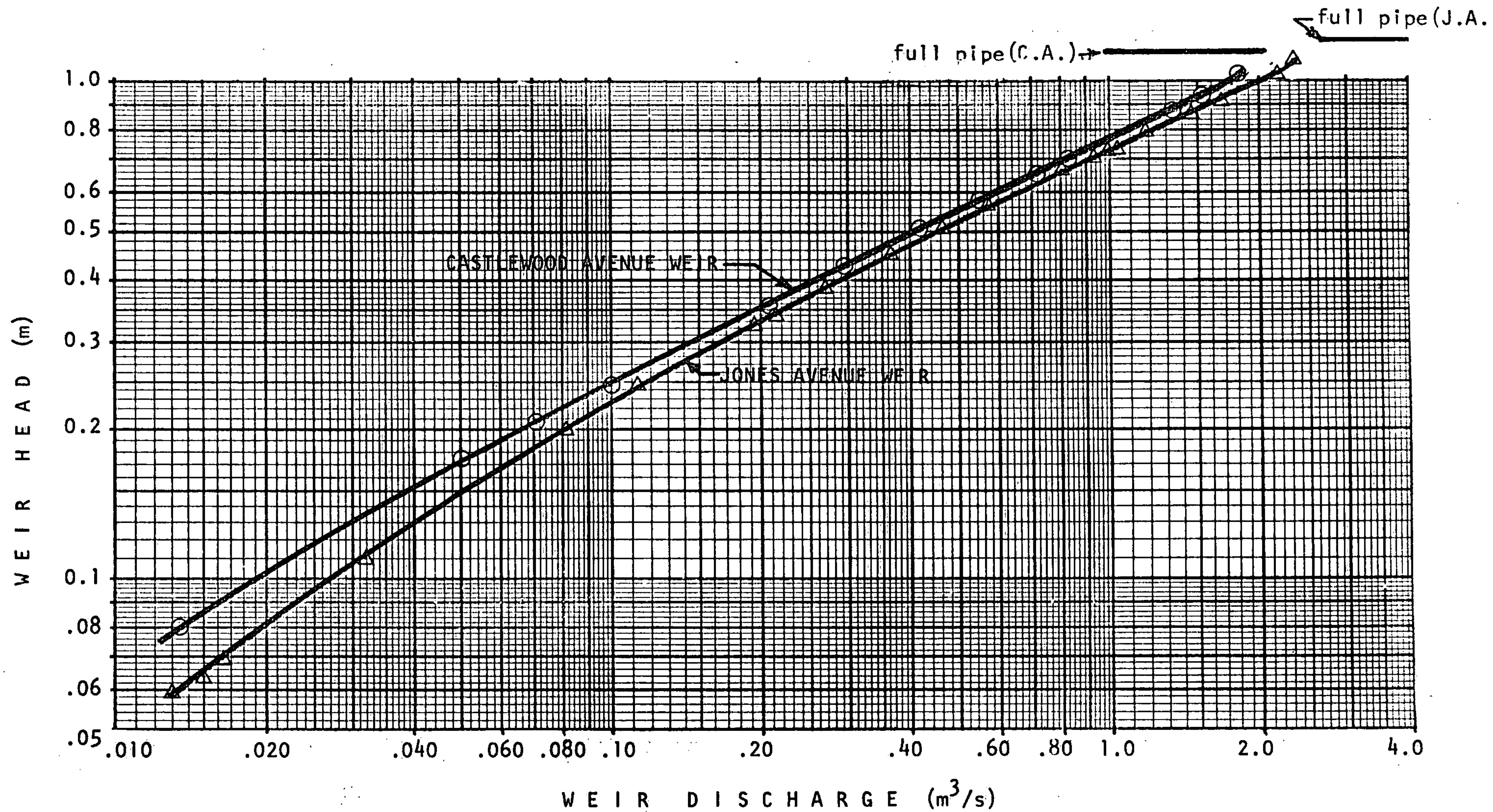


Fig.2. RATING CURVES FOR CASTLEWOOD AND JONES AVENUE WEIRS(Prototype Dimensions)

manhole will be above the benching and may not be identical to the level in the sewer pipe (i.e. as measured in this report). There are two possible remedies:

(1) Extend the existing benching at the manhole above the 0.5 D level, e.g. by the addition of a wooden structure approximating the sewer pipe shape.

(2) Relocate the weir head measuring point inside the sewer pipe and use an applicable water level sensor.

Alternatively, the model would have to be modified at a fairly high cost ($400) and a manhole structure added to the model pipe.

A possible disagreement between the flow depth readings at the manhole and inside the sewer pipe was further investigated by analyzing some experimental data from an ongoing study. For a pipe slope of 0.1%, the depths at the manhole were, on average, larger by 0.3 inch (prototype value) than those inside the sewer pipe.

6. Conclusions

The rating curves produced allow a good characterization of flows at both weir installations. For the conditions modelled in the laboratory (i.e. the weir head is measured inside the sewer pipe), a flow measurement accuracy of ±5% can be expected at both installations.

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