Appendix 9-3 Drainage Design Calculations

1. Introduction

CDM Smith Ireland Ltd (CDM Smith) was requested by MKO, on behalf of Sheskin South Renewables Power Designated Activity Company (DAC), to calculate drainage rates and volumes associated with planned wind farm development (Proposed Development) at Sheskin, Co. Mayo.

1.1 Purpose of Assessment

The purpose of the calculations is to estimate and communicate drainage rates and volumes of runoff from greenfield areas and infrastructure locations within the Proposed Development site. The calculations serve to guide the planning of drainage for construction and operations of the Proposed Development.

The calculations specifically address 'greenfield' runoff within Sheskin Forest and runoff from access roads and hardstanding that accompany the different infrastructure components of the Proposed Development.

The calculations make use of information from Chapter 2 (Project Description) and Chapter 9 (Hydrology and Hydrogeology) of the EIAR. The calculations have been prepared in conjunction with the proposed drainage layout presented in Appendix 4-4.

1.2 Statement of Authority

Established in Ireland since 2001, CDM Smith's ISO 9001, ISO 14001 and OHSAS 18001 - accredited Dublin office works on a diverse range of water and environmental projects for public and private sector clients, including the preparation of drainage designs for flood risk and environmental protection initiatives.

The calculations presented herein were prepared by Henning Moe (registered P. Geo.), a hydrogeologist with over 30 years of practical experience, supported by Masoud Mahdisoltani, a water resources engineer with 6 years of experience conducting hydraulic analyses for flood hazard studies and drainage network designs. Jon Hunt (registered P. Geo.), a geologist with over 20 years of practical experience, conducted site walkover surveys, and Ruairi O'Carroll (CEng MIEI), a chartered engineer with over 20 years of practical experience, provided technical review.

2. Basis of Calculations

2.1 Greenfield Runoff

Greenfield runoff represents 'clean water' which is intercepted upstream of access roads and infrastructure components of the Proposed Development. This water is led to existing forestry drains or water courses (i.e., where the runoff water already discharges).

Calculations are based on the 'IH-124 method' for small catchments (Marshall and Bayliss, 1994) which is a pragmatic and commonly applied method for this type of assessment. The IH-124 method calculates 'Qbar' which is the peak rate of flow from a subcatchment for the mean annual flood with a return period of approximately 2 years. Qbar is calculated from the following equation:

$$\text{Qbar } (m^3/s) = 0.00108 \times (0.01 \times \text{AREA})^{0.89} \times \text{SAAR}^{1.17} \times \text{SPR}^{2.17}$$

Where,

- AREA = subcatchment area (m^2).

- SAAR = standard annual average rainfall (mm/yr).
- SPR = standard percentage runoff coefficient for the applicable SOIL category in the subcatchment area. The SOIL category is measure of winter rainfall acceptance potential, as a percent of rainfall. Soils are classified from S1 to S5 based on runoff potential. S1 has a low runoff value while S5 has a higher runoff potential.

Qbar, which is an 'index flood' (a mean annual peak flood) was subsequently modified to a 'design flood' for a 1 in 10 year storm event by multiplying Qbar with a national flood frequency growth factor of 1.35 for a 1 in 10 year return period storm, based on Cawley and Cunnane, 2003. This raises the greenfield runoff volume to account for rainfall conditions that are reflected by storm-events rather than an annual average.

2.2 Runoff from Access Roads and Hardstanding

Runoff from new access roads and hardstanding represents 'dirty water' which is intercepted by engineered swales downstream of access roads and infrastructure components. The water is led to settlement (stilling) ponds before being discharged to nearby streams. These are established prior to construction of facilities, and the swales and ponds remain in place during all subsequent phases of the Proposed Development.

Runoff calculations for access roads and hardstanding are based the 'Rational Method' (Mulvaney, 1851), which is represented by the following equation:

$$Q = c \times I \times A$$

Where,

- Q = peak runoff rate (m^3/s).
- c = runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff.
- I = rainfall intensity for the design return period (mm/hr).
- A = subcatchment area (m^2)

A conservative instantaneous time of entry is assumed. The calculation was carried out for a 6-hour duration, 1 in 10 year return period, storm. The duration of construction of the Proposed Development is 2 years (maximum), and it is reasonable to expect a 1 in 10 year storm event during this construction period.

2.3 Sizing of Settlement Ponds

The sizing of settlement ponds incorporated in the drainage of 'dirty water' is based on the following equation:

$$A = Q/Vs$$

Where:

- A = area of pond (m^2)
- Q = flow into pond (m^3/s)
- Vs = settling velocity (m/s) of fine silt-grade particles, selected to be 10 µm (0.01 mm) in size, reflecting the need to settle out fines given the Water Framework Directive (WFD) High Status objective and High Status (2016-2021) of the Sheskin River (see Appendix 9-4).

Vs is calculated from Stoke's Law:

$$Vs = [2 \times r^2 \times g \times (D_p - D_f)] / (9\ n)$$

Where,

- r is the radius of the particle (m)
- g is gravity (9.80665 m/s^2)
- D_p is the density of the particles (kg/m^3), taken to be 2,400 kg/m^3
- D_f is the density of the fluid (kg/m^3), taken to be 1,000 kg/m^3
- n is the dynamic viscosity of the fluid (0.001308 kg/ m sec @ 10°C)

Hence, for a 10 µm particle, Vs = 0.000234 m/s.

3. Results

3.1 Greenfield Runoff

Runoff calculations from subcatchments of greenfield areas are presented in **Table 1**. The subcatchments were delineated from detailed topographic maps based on Lidar surveys and are presented in Chapter 9 of the EIAR. The calculated Qbar values range from 0.001 to 0.381 m^3/s, for a sum of 7.038 m^3/s.

Table 1: Calculated Greenfield Runoff Rates

Subcatchment	Subcatchment Area (m^2)	As % of Proposed Development Site	Qbar (m^3/s)
A1	49,480.9	0.4%	0.096
A2	63,564.8	0.5%	0.119
A3	70,810.6	0.6%	0.131
A4	6,102.2	0.1%	0.015
A5	29,862.6	0.3%	0.061
A6	55,369.6	0.5%	0.105
A7	81,072.3	0.7%	0.149
A8	63,598.0	0.5%	0.119
A9	20,931.9	0.2%	0.045
A10	82,014.1	0.7%	0.150
A11	75,306.2	0.6%	0.139
A12	11,280.7	0.1%	0.026
A13	99,810.0	0.8%	0.178
A14	156,603.9	1.3%	0.266
A15	75,740.5	0.6%	0.139
A16	109,866.1	0.9%	0.194
A17	39,677.2	0.3%	0.078
A18	140,920.2	1.2%	0.242
A19	29,837.8	0.0%	0.001
A20	21,131.7	0.3%	0.061
A21	167,646.7	0.2%	0.045
A22	71,449.3	1.4%	0.282
A23	235,536.8	0.6%	0.132

Subcatchment	Subcatchment Area (m^2)	As % of Proposed Development Site	Qbar (m^3/s)
A24	102,652.0	2.0%	0.381
A25	24,958.0	0.9%	0.182
A26	232,751.4	0.2%	0.053
A27	19,220.3	2.0%	0.377
A28	65,561.9	0.2%	0.042
A29	24,050.0	0.6%	0.123
A30	24,638.1	0.2%	0.050
A31	65,648.8	0.2%	0.051
A32	53,565.2	0.6%	0.123
A33	171,330.0	0.5%	0.103
A34	76,753.1	1.4%	0.288
A35	17,781.9	0.6%	0.140
A36	78,078.3	0.1%	0.039
A37	52,256.2	0.7%	0.143
A38	157,457.5	0.4%	0.100
A39	113,716.0	1.3%	0.266
A40	141,954.3	1.0%	0.200
A41	38,393.3	1.2%	0.243
A42	14,339.3	0.3%	0.077
A43	31,091.7	0.1%	0.032
A44	100,076.4	0.3%	0.063
A45	4,982.6	0.8%	0.178
A46	117,731.0	0.0%	0.014
A47	26,011.7	1.0%	0.207
A48	76,327.2	0.2%	0.054
A49	49,692.6	0.6%	0.140
A50	218,035.0	0.4%	0.096
A51	10,061.6	1.8%	0.356
A52	22,190.1	0.1%	0.024
A53	37,097.7	0.2%	0.047
Sum	**3,888,920**	**32.8%**	**7.038**

3.2 Runoff From Access roads and Hardstanding

Based on Chapter 9 of the Hydrology and Hydrogeology Chapter, the rainfall depth for the 6-hour, 10-year storm event is 41.6 mm, which equates to a rainfall intensity of 6.93 mm/hr.

For access roads and hardstanding, a runoff coefficient of 0.7 was used (i.e., relatively impermeable). From this:

$$Q = 0.7 \times [(6.93/1{,}000)/3{,}600] \times 1 = 1.35\times10^{-6}\ m^3/s \text{ per unit area (one } m^2\text{).}$$

Q was subsequently calculated up based on relative areas to give runoff rates for the various components of the Proposed Development, as presented in **Table 2**.

Table 2: Calculated Runoff From Access roads and Hardstanding

Item	Construction Area (m^2)	Runoff Generated (m^3/s) - Rounded
Hardstanding and Crane Pads for Turbines	90,405	0.122
New Access roads	100,473	0.136
Existing Access roads to be Upgraded[1]	46,883	0.063
Construction Compounds[2]	12,308	0.017
Electrical Substation	21,500	0.029
Met Mast Platform	294	0.0004
Sum	**271,863**	**0.367**

Notes:
[1]Existing tracks are c. 4 m wide and require a 2 m upgrade in width. The area shown is for 6 m wide upgraded roads.
[2]Total for 4 no. compounds of equal size.

3.3 Sizing of Settlement Ponds

To be able to settle out particles of ten µm, the pond area required is calculated from:

Area = Q/Vs

Where,

Q = the flow rate into the pond (m^3/s).

Vs = settling velocity of particles of 10 µm based on Stoke's Law = 0.000234 m/s.

Results of total pond area requirements for each component of the Proposed Development is presented in **Table 3**.

Table 3: Calculated Pond Area Requirements To Settle Out 10 µm Particles

Item	Runoff Generated (m^3/s) - Rounded	Pond Area Required (m^2) - Rounded
Hardstanding and Crane Pads for Turbines	0.122	521.4
New Access roads	0.136	581.2
Existing Access roads to be Upgraded[1]	0.063	269.2
Construction Compounds[2]	0.017	72.6
Electrical Substation	0.029	123.9
Met Mast Platform	0.0004	1.7
Sum	**0.367**	**1,570.0**

There are:

- 21 no. turbines, which means that each turbine site requires a pond of 24.9 m^2 on average.
- 4 no. construction compounds of equal size, which means that each compound requires a pond of 18.2 m^2.
- The electrical substation and met mast are individual components, requiring the pond areas indicated in **Table 3**, i.e., 123.9 and 1.7 m^2, respectively.

- The new and existing access roads require a total pond area of 850.4 m^2, across a total length of 22 km, which equates to 38.7 m^2 per km length of access roads.

It is envisaged that construction of individual ponds will be limited to areas of 20 to 30 m^2 (longer than wider). These are practical dimensions from a constructability of view, using standard equipment, and assume pond depths of <1.5 m.

4. References

Marshall, D.C.W. & Bayliss, A.C. 1994. Flood estimation for small catchments, Institute of Hydrology Report No. 124, Institute of Hydrology, Wallingford.

Cawley, A.M., and Cunnane, C. (2003). Comment on Estimation of Greenfield Runoff Rates. Proc. IHP National Hydrology Seminar, Tullamore, Ireland. Accessible from: https://hydrologyireland.ie/wp-content/uploads/2020/12/2-Comment-on-Estimation-of-Greenfield-Runoff-Rates-E_Cawley-Cunnane.pdf

Mulvany, T.J. (1851). On the use of self-registering rain and flood gauges in making observations of the relations of rain fall and of flood discharges in a given catchment. Proceedings of the Institution of Civil Engineers of Ireland 4, 18–33. Reproduced in Loague (2010) Rainfall-Runoff Modelling, Benchmark Papers in Hydrology, IAHS BM4 ISBN 978-1-907161-06-3.