



## APPENDIX 9-4

**DRAINAGE DESIGN  
CALCULATIONS**

# 1. INTRODUCTION

The Proposed Project is described fully in Chapter 4: *'Description of the Proposed Project'* of the Environmental Impact Assessment Report (EIAR). During construction and operations of the Proposed Project, surface runoff will have to be managed and led to the local tributaries and rivers via new and existing drains.

The proposed drainage layout is presented in **Appendix 4-2** of the EIAR. This appendix (of Chapter 9: *'Hydrology and Hydrogeology'*) presents calculations of estimated drainage water volumes for the Proposed Project.

## 1.1 Purpose

The purpose of this appendix is to communicate estimated drainage water volumes and how they were calculated. The calculations cover i) runoff from greenfield areas and ii) runoff from infrastructure hardstand areas. The former will be captured by interceptor drains immediately upslope from infrastructure components, including access roads. The latter will be captured by swales constructed downslope of the same infrastructure components.

## 1.2 Statement of Authority

The calculations presented herein were prepared by Henning Moe (registered P. Geo.), a hydrogeologist with over 30 years of practical experience. The calculations are guided by prior drainage planning experience from the Sheskin and Glenora wind farm EIARs in Co. Mayo, approved by An Coimisiún Pleanála (ACP) in 2023 and 2025, respectively.

Henning was supported by Dr Bebhinn Anders (registered P. Geo.) and Colin Fitzgerald, both geologists with relevant practical field experience who participated in site walkover surveys, and by Joseph O'Brien, a CADD/Civil 3D specialist who prepared the drainage layout drawings in **Appendix 4-2**.

## 2. BASIS OF CALCULATIONS

### 2.1 Greenfield Runoff

Interceptor drains capture and leads greenfield runoff towards natural water courses, either directly or via nearby field- and plantation drains, depending on location. The new interceptor drains are integrated with existing field drains that have been dug by farmers for land improvement purposes, and with existing plantations drains that are part of Coillte's forestry operations. The captured runoff water is led to settling basins/ponds before being discharged diffusely using level spreaders across vegetated grounds.

Calculations of greenfield runoff were initially performed using the IH-124 method for small catchments, <25 km<sup>2</sup> (Marshall and Bayliss, 1994). The IH-124 method, which is a commonly applied method for this type of assessment, calculates values of 'Q<sub>bar</sub>' for each of the infrastructure subcatchments shown in **Figure 2-1**, delineated using Lidar survey data (1 m contour interval). Q<sub>bar</sub> is an annual average maximum flood defined as the “peak rate of flow from a subcatchment for the mean annual flood with a return period of approximately 2 years”.

Q<sub>bar</sub> is calculated from the following equation:

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

where,

- › AREA = subcatchment area (km<sup>2</sup>).
- › SAAR = standard annual average rainfall (mm/yr), ca. 1,250 mm/yr based on Met Éireann long-term average annual rainfall grid for the 30-year period 1981-2010.
- › 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, and related input values range from 0.1 to 0.5. For the Proposed Project site, a value of 0.3 was selected across most of the catchment, reflecting moderately steep slopes and moderate permeability subsoils. A value of 0.4 was used in subcatchments in the southeast of the Proposed Project site, reflecting peaty, less well drained soils and lower permeability subsoils.

As the ‘index flood’ (an average annual peak flood), Q<sub>bar</sub> was also adjusted up to a ‘design flood’ by:

- › Multiplying Q<sub>bar</sub> by a national flood frequency growth factor of 1.35 for a 1 in 10-year return period storm (Cawley and Cunnane, 2003).
- › Multiplying the resulting values further by 20% (i.e., 1.2) to conservatively account for climate change (Cawley and Cunnane, 2003).

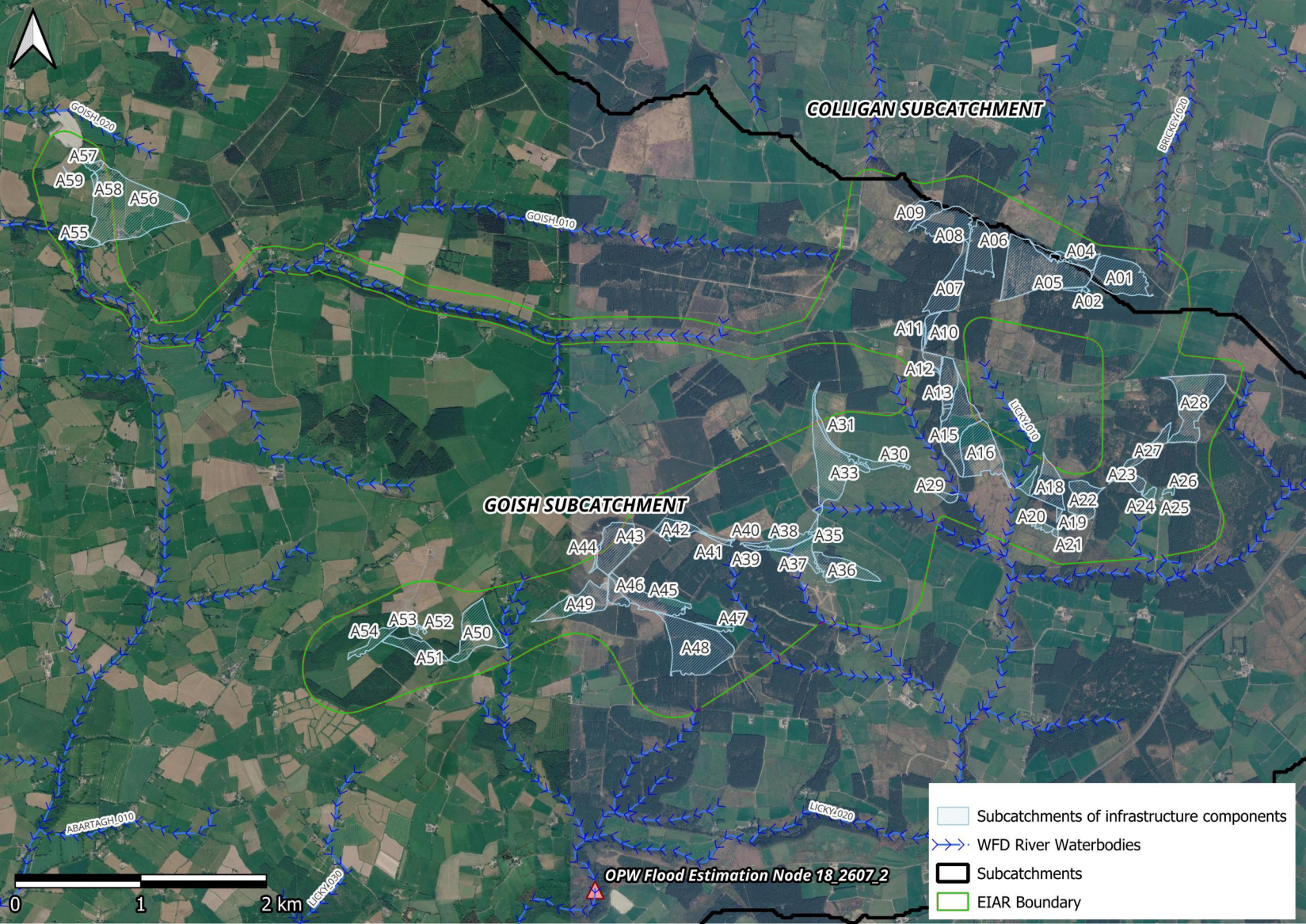
Q<sub>bar</sub> was then compared to calculations of Q<sub>med</sub>, which is a “median annual flood”.<sup>1</sup> Calculations of Q<sub>med</sub> were conducted using the ‘flood estimation package’ for ungauged locations made publicly available by the Office of Public Works (OPW) in 2025. This package comprises a “FSU spreadsheet” and related GIS layers.<sup>2</sup> The Q<sub>med</sub> calculation is based on multivariate regression equations (e.g. Gebre and Nicholson 2012) of physical catchment descriptors such as AREA, SAAR, and the Baseflow Index (BFI), specifically:

$$Q_{\text{med}} \text{ (m}^3\text{/s)} = 3.117 \times 10^{-6} \times \text{AREA}^{1.07} \times \text{BFI}_{\text{soils}}^{-1.342} \times \text{SAAR}^{1.351} \times \text{FARL}^{2.419} \times \text{DRAIN}^{0.272} \times \text{S1085}^{0.185} \times (1 + \text{ARTDRAIN2})^{0.53}$$

<sup>1</sup> <https://www.ceh.ac.uk/services/flood-estimation-handbook>

<sup>2</sup> <https://www.floodinfo.ie/fsu/>

The flood estimation package incorporates default values for each, based on selected locations (prescribed nodes in the GIS coverage).



## 2.2 Runoff from Access Roads and Hardstand Areas

Runoff from access roads and hardstand areas will be captured by swales that are constructed downslope of all infrastructure components. The captured runoff water is led to settling basins/ponds before being discharged to nearby streams. The swales and settling ponds are particularly important for the construction phase but will remain in place during all subsequent phases of the Proposed Project.

The runoff calculations for access roads and hardstand areas are based the 'Rational Method' (Mulaney, 1851), which is represented by the following equation:

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

where,

- > Q = peak runoff rate (m<sup>3</sup>/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<sup>2</sup>)

The calculation considered a 6-hour duration, 1 in 10-year return period storm. The duration of construction of the Proposed Project is 2 years (maximum), and a 1 in 10-year storm event can reasonably be expected to occur during the construction period.

## 2.3 Sizing of Settlement Ponds

The sizing of settlement ponds is based on the following equation:

$$A = Q/V_s$$

where,

- > A = area of pond (m<sup>2</sup>)
- > Q = flow into pond (m<sup>3</sup>/s), from Section 2.2 above.
- > V<sub>s</sub> = 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.

V<sub>s</sub> is calculated from Stoke's Law:

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

where,

- > r is the radius of the particle (m)
- > g is gravity (9.80665 m/s<sup>2</sup>)
- > D<sub>p</sub> is the density of the particles (kg/m<sup>3</sup>), taken to be 2,400 kg/m<sup>3</sup>
- > D<sub>f</sub> is the density of the fluid (kg/m<sup>3</sup>), taken to be 1,000 kg/m<sup>3</sup>
- > η is the dynamic viscosity of the fluid (0.001308 kg/ m sec @ 10°C)

Hence, for a 10 µm sized silt particle (radius 5 µm), V<sub>s</sub> = 0.0000583 m/s (or 5.04 m/d).

## 2.4 Flows to Guide the Sizing of Culverts

The high rainfall amounts and steep slopes in parts of the Site require that pipe culverts and water crossing structures be oversized in a subsequent design phase in order to mitigate the potential for causing damage to access roads and excessive erosion. Hence, conservative runoff volumes were estimated based on the publication “Drainage of Runoff from Natural Catchments” published by Transport Infrastructure Ireland (TII, 2015), whereby  $Q_{bar}$  was adjusted up for design storms with a return period of 75 years, accounting for:

- › The revised national growth curve for Ireland of approximately 1.77 for a 75-year storm event (average of 1 in 50 and 1 in 100-year storm values, per Cawley and Cunnane, 2003).

The standard factorial error (SFE) of 1.65, per method IH 124, for culvert designs. A 20% increase to  $Q_{bar}$  values (adjusted), to account for climate change.

## 3. RESULTS

### 3.1 Greenfield Runoff

#### 3.1.1 $Q_{bar}$

The runoff calculations from greenfield subcatchments are presented in **Table 3-1**. Calculated  $Q_{bar}$  values for the different subcatchments range from <0.001 to 0.15 m<sup>3</sup>/s, for a sum of 1.3 m<sup>3</sup>/s (rounded). Adjusted up to account for 1 in 10-year design floods and climate change, the design flood  $Q_{bar}$  values range from 0.002 to 0.25 m<sup>3</sup>/s, for a sum of 2.14 m<sup>3</sup>/s (rounded).

Table 3-1: Calculated  $Q_{bar}$  as Greenfield Runoff

| Subcatchment | Subcatchment Area (m <sup>2</sup> ) | $Q_{bar}$ Annual Average Maximum Flood (m <sup>3</sup> /s) | $Q_{bar}$ Design Flood (m <sup>3</sup> /s) |
|--------------|-------------------------------------|------------------------------------------------------------|--------------------------------------------|
| A1           | 102,913                             | 0.046                                                      | 0.076                                      |
| A2           | 4,747                               | 0.003                                                      | 0.005                                      |
| A3           | 8,168                               | 0.005                                                      | 0.008                                      |
| A4           | 18,583                              | 0.010                                                      | 0.018                                      |
| A5           | 199,038                             | 0.083                                                      | 0.134                                      |
| A6           | 67,997                              | 0.032                                                      | 0.052                                      |
| A7           | 77,985                              | 0.036                                                      | 0.059                                      |
| A8           | 75,792                              | 0.035                                                      | 0.059                                      |
| A9           | 34,307                              | 0.017                                                      | 0.029                                      |
| A10          | 10,889                              | 0.006                                                      | 0.011                                      |
| A11          | 3,848                               | 0.002                                                      | 0.005                                      |
| A12          | 12,862                              | 0.007                                                      | 0.013                                      |
| A13          | 42,817                              | 0.021                                                      | 0.036                                      |
| A14          | 5,756                               | 0.004                                                      | 0.006                                      |
| A15          | 108,814                             | 0.048                                                      | 0.079                                      |
| A16          | 114,159                             | 0.050                                                      | 0.083                                      |
| A17          | 10,914                              | 0.006                                                      | 0.011                                      |
| A18          | 59,554                              | 0.028                                                      | 0.047                                      |
| A19          | 2,911                               | 0.002                                                      | 0.004                                      |
| A20          | 8,883                               | 0.005                                                      | 0.010                                      |
| A21          | 2,498                               | 0.002                                                      | 0.004                                      |
| A22          | 55,907                              | 0.027                                                      | 0.043                                      |
| A23          | 15,426                              | 0.009                                                      | 0.014                                      |
| A24          | 6,724                               | 0.004                                                      | 0.008                                      |
| A25          | 422                                 | 0.000                                                      | 0.001                                      |
| A26          | 3,815                               | 0.002                                                      | 0.005                                      |
| A27          | 32,652                              | 0.017                                                      | 0.028                                      |
| A28          | 134,779                             | 0.059                                                      | 0.096                                      |
| A29          | 12,146                              | 0.007                                                      | 0.011                                      |
| A30          | 16,229                              | 0.009                                                      | 0.014                                      |
| A31          | 8,924                               | 0.005                                                      | 0.010                                      |
| A32          | 3,159                               | 0.002                                                      | 0.005                                      |
| A33          | 128,710                             | 0.056                                                      | 0.092                                      |

| Subcatchment | Subcatchment Area (m <sup>2</sup> ) | Q <sub>bar</sub> Annual Average Maximum Flood (m <sup>3</sup> /s) | Q <sub>bar</sub> Design Flood (m <sup>3</sup> /s) |
|--------------|-------------------------------------|-------------------------------------------------------------------|---------------------------------------------------|
| A34          | 3,049                               | 0.002                                                             | 0.005                                             |
| A35          | 3,850                               | 0.002                                                             | 0.005                                             |
| A36          | 64,053                              | 0.030                                                             | 0.050                                             |
| A37          | 31,700                              | 0.016                                                             | 0.028                                             |
| A38          | 33,804                              | 0.017                                                             | 0.029                                             |
| A39          | 4,614                               | 0.003                                                             | 0.005                                             |
| A40          | 417                                 | 0.000                                                             | 0.001                                             |
| A41          | 6,008                               | 0.004                                                             | 0.006                                             |
| A42          | 35,703                              | 0.018                                                             | 0.029                                             |
| A43          | 89,207                              | 0.041                                                             | 0.066                                             |
| A44          | 5,292                               | 0.003                                                             | 0.006                                             |
| A45          | 71,766                              | 0.033                                                             | 0.055                                             |
| A46          | 20,653                              | 0.011                                                             | 0.019                                             |
| A47          | 7,863                               | 0.005                                                             | 0.008                                             |
| A48          | 173,994                             | 0.073                                                             | 0.120                                             |
| A49          | 82,045                              | 0.038                                                             | 0.061                                             |
| A50          | 98,881                              | 0.044                                                             | 0.073                                             |
| A51          | 46,810                              | 0.023                                                             | 0.037                                             |
| A52          | 1,863                               | 0.002                                                             | 0.004                                             |
| A53          | 6,166                               | 0.005                                                             | 0.010                                             |
| A54          | 25,540                              | 0.019                                                             | 0.031                                             |
| A55          | 10,510                              | 0.008                                                             | 0.014                                             |
| A56          | 285,541                             | 0.160                                                             | 0.259                                             |
| A57          | 9,061                               | 0.007                                                             | 0.013                                             |
| A58          | 3,604                               | 0.003                                                             | 0.006                                             |
| A59          | 2,822                               | 0.003                                                             | 0.005                                             |
| <b>TOTAL</b> | <b>2,517,144</b>                    | <b>1.288</b>                                                      | <b>2.138</b>                                      |

Broken down by which river the greenfield runoff will be directed to, the relative areas of related subcatchments and volumes of water are summarised in **Table 3-2**.

Table 3-2: Calculated Q<sub>bar</sub>, as Greenfield Runoff, by Surface Water Receptor

| Infrastructure Subcatchment Nos. | Total Area (m <sup>2</sup> ) | % of Total Subcatchment Area | Q <sub>bar</sub> as the Annual Average Maximum Flood (m <sup>3</sup> /s) | Q <sub>bar</sub> as a Design Flood (m <sup>3</sup> /s) |
|----------------------------------|------------------------------|------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------|
| <b>BRICKEY RIVER</b>             |                              |                              |                                                                          |                                                        |
| A1, A4                           | 121,496                      | 5                            | 0.054                                                                    | 0.088                                                  |
| <b>LICKY RIVER</b>               |                              |                              |                                                                          |                                                        |
| A2, A3, A5 to A54                | 2,084,110                    | 83                           | 1.061                                                                    | 1.764                                                  |
| <b>GOISH RIVER</b>               |                              |                              |                                                                          |                                                        |
| A55 to A59                       | 311,538                      | 12                           | 0.173                                                                    | 0.287                                                  |

The resulting average specific runoff (runoff per unit area) for the calculated Q<sub>bar</sub> is 0.5 m<sup>3</sup>/s/km<sup>2</sup>.

### 3.1.2 $Q_{med}$

As a check on the specific runoff estimate derived from  $Q_{bar}$  in **Table 3-2**, ' $Q_{med}$ ' was calculated for a nodal location (node 18\_2607\_2) on the Licky River immediately downstream of the EIAR boundary (refer to **Figure 2-1**). The nodal location has a subcatchment area of 33 km<sup>2</sup>, and at this location, the calculated  $Q_{med}$  (using default values in OPW's flood estimation package) is 5.44 m<sup>3</sup>/s (rounded). Compared to  $Q_{bar}$ , the  $Q_{med}$  result produces a considerably smaller specific runoff value, as indicated in **Table 3-3**.

Table 3-3: Calculated Specific Runoff from Values of Adjusted  $Q_{bar}$  and  $Q_{med}$

|           | Area<br>(km <sup>2</sup> )                          | Calculated Sum<br>(m <sup>3</sup> /s) | Specific Runoff<br>(m <sup>3</sup> /s/km <sup>2</sup> ) |
|-----------|-----------------------------------------------------|---------------------------------------|---------------------------------------------------------|
| $Q_{bar}$ | 2.1<br>(subcatchments of infrastructure components) | 1.061                                 | 0.51                                                    |
| $Q_{med}$ | 33<br>(subcatchment of selected node)               | 5.440                                 | 0.16                                                    |

The difference is attributed to the respective calculation methods and differences in input values, including SAAR. For example, the OPW flood estimation package uses a default SAAR value of 1,073 mm/yr at the selected nodal location. Based on gridded rainfall data from Met Éireann for the Licky River catchment, the value of 1,073 mm/year seems low. The long-term average annual rainfall given by Met Éireann for the centre point of the Proposed Project is 1,250 mm/yr, which was applied to the  $Q_{bar}$  calculation. If the higher value of 1,250 mm/yr is applied in the  $Q_{med}$  method, then  $Q_{med}$  increases to 6.7 m<sup>3</sup>/s, and the specific runoff becomes 0.21 m<sup>3</sup>/s/km<sup>2</sup>. Conversely, if the  $Q_{med}$  specific runoff value is applied to each of the individual subcatchment areas, the total greenfield runoff, as  $Q_{bar}$ , reduces from 1.29 to 0.5 m<sup>3</sup>/s.

A potential issue with  $Q_{med}$  in this context is that the regression analyses behind the method inputs do not factor in recent climate data which incorporate some of the wettest years on record. There are ways to compensate for this, but for planning purposes, the  $Q_{bar}$  values for the subcatchments of individual infrastructure component were carried forth, as conservatively high values.

## 3.2 Runoff From Access Roads and Hardstand Areas

Based on Chapter 9 of the EIAR, the rainfall depth for the 6-hour duration, 10-year return period storm event within the Proposed Project area is 43.9 mm, which equates to a rainfall intensity of 7.3 mm/hr.

For access roads and hardstand areas (which are not paved), a runoff coefficient of 0.7 was used (i.e., relatively impermeable). Thus:

$$Q = 0.7 \times [(7.3/1,000)/3,600] \times 1 = 1.42 \times 10^{-6} \text{ m}^3/\text{s per unit area (one m}^2\text{)}.$$

The value of  $Q$  was subsequently applied to the construction areas of different infrastructure components, as presented in **Table 3-4**.

Table 3-4: Calculated Runoff from Access Tracks and Hardstand Areas

| Item                                               | Construction Area (m <sup>2</sup> ) | Runoff Generated (m <sup>3</sup> /s) - Rounded |
|----------------------------------------------------|-------------------------------------|------------------------------------------------|
| Hardstand and Crane Pads for Turbines              | 94,770                              | 0.135                                          |
| New Access Tracks <sup>1</sup>                     | 85,956                              | 0.122                                          |
| Existing Access Tracks to be Upgraded <sup>1</sup> | 44,932                              | 0.064                                          |
| Construction Compounds (6 no.)                     | 11,004                              | 0.016                                          |
| Electrical Substations (2 no.)                     | 32,238                              | 0.046                                          |
| Borrow Pits (5 no.)                                | 63,225                              | 0.090                                          |
| Met Mast Platform                                  | 20                                  | negligible                                     |
| <b>TOTAL</b>                                       | <b>332,145</b>                      | <b>0.471</b>                                   |

Notes:

<sup>1</sup> Assumed five metre running surface with six-metre-wide footprint.

### 3.3 Estimated Sizing of Settlement Ponds

To be able to settle out particles of 10 µm, pond area requirements are calculated from:

$$\text{Area} = Q/V_s$$

where,

Q = the flow rate into the pond (m<sup>3</sup>/s).

V<sub>s</sub> = settling velocity of particles of 10 µm based on Stoke's Law = 0.0000583 m/s.

Results of total pond area requirements for each component of the Proposed Project are presented in **Table 3-5**.

Table 3-5: Calculated Pond Area Requirements to Settle Out 10 µm Particles

| Item                                  | Runoff Generated (m <sup>3</sup> /s) - Rounded | Pond Area Required (m <sup>2</sup> ) - Rounded |
|---------------------------------------|------------------------------------------------|------------------------------------------------|
| Hardstand and Crane Pads for Turbines | 0.135                                          | 2,307                                          |
| New Access Tracks                     | 0.122                                          | 2,093                                          |
| Existing Access Tracks to be Upgraded | 0.064                                          | 1,094                                          |
| Construction Compounds (6 no.)        | 0.016                                          | 268                                            |
| Electrical Substations (2 no.)        | 0.046                                          | 785                                            |
| Borrow Pits (5 no.)                   | 0.090                                          | 1,539                                          |
| Met Mast Platform                     | negligible                                     | negligible                                     |
| <b>TOTAL</b>                          | <b>0.471</b>                                   | <b>8,086</b>                                   |

Practically, the individual pond areas will be up to 30 m<sup>2</sup>, based on dimensions of 3×10 m, with a pond depth of 1 m.

The new and existing access road upgrades require a total pond area of 3,187 m<sup>2</sup>, across a total length of 21.8 km, which equates to 146 m<sup>2</sup> per km length of road and access tracks, on average, or just under 5 ponds per km length.

## 3.4 Guide to Sizing of Culverts

As presented in **Appendix 4-2**, the drainage of the proposed infrastructure will require the upgrade and/or installation of approximately 59 piped culverts to accommodate the preliminary drainage layout. Existing pipe culverts observed during the site walkover survey range in diameter from 100 to 600 mm.

To confirm culvert size requirements, the calculations of design floods were compared against the flow capacities of plastic/HDPE and concrete pipe materials. Assuming 10 m average lengths of culverts and a 0.5 m head drop across culverts, calculated flow capacities of PVC/HDPE and concrete pipes are summarised in **Table 3-6**.

*Table 3-6: Calculated Pipe Flow Capacities (Gravity Flow) for Different Diameter Pipes*

| Pipe Diameter (mm) | Calculated Flow Capacity (m <sup>3</sup> /s) <sup>1</sup> |                       |
|--------------------|-----------------------------------------------------------|-----------------------|
|                    | Plastic/HDPE <sup>2</sup>                                 | Concrete <sup>3</sup> |
| 300                | 0.256                                                     | 0.217                 |
| 400                | 0.550                                                     | 0.465                 |
| 500                | 0.998                                                     | 0.844                 |
| 600                | 1.623                                                     | 1.375                 |
| 900                | 4.784                                                     | 4.408                 |
| 1200               | 10.303                                                    | 8.717                 |

Notes:

<sup>1</sup> Assumed flowing full but not pressurised. Based on Manning's equation under TII guidance DN-DNG-03022

<sup>2</sup> For smooth plastic/HDPE pipe, n = 0.011

<sup>3</sup> For relatively smooth pre-cast concrete pipe, n = 0.013

Based on the maximum adjusted  $Q_{bar}$  value of 2.021 m<sup>3</sup>/s, the maximum pipe diameter that will be needed to accommodate the indicative 1 in 100-year design flow is 900 mm for both PVC/HDPE and concrete pipes. These estimates do not factor in potential flow velocity constraints or potential scour effects which will have to be considered during actual design of any given culvert.

## 4. REFERENCES

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