

11 HYDROLOGY

This section describes the existing hydrological conditions at the site, and the potential impacts of the proposed scheme. Mitigation measures to ameliorate any adverse impacts are also identified.

The following key issues are considered in relation to the development:

- Modifications to natural drainage patterns.
- Impacts on runoff and baseflow;
- Impacts on groundwater;
- Impacts on water quality and water supplies.
- Impacts on flow in natural watercourses and flush zones.
- Modification of stream channel morphology (erosion/deposition)
- Modification of site ecology

11.1 Assessment Methodology

11.1.1 Data Sources

The following data sources have been referred to in this assessment:

- Ordnance Survey Landranger sheets 28 (Elgin & Dufftown) and 37 (Strathdon) at 1:50,000 scale.
- Soil Survey of Scotland. 1:250,000 scale Sheet 5 Eastern Scotland. Macaulay Institute for Soil Research 1982.
- FCS unpublished soil survey for Clashindarroch Forest, paper maps at 1:10,560 (held at FCS, Huntly).
- Geological Survey of Scotland. Sheets 75E (Scotland) Glenbuchat 1:50,000; 76W (Scotland) Alford 1:50,000; 85E (Scotland) Glenfiddich 1:50,000; 86 Huntly 1:63,360 (Solid and Drift Geology)
- Flood Estimation Handbook CD-ROM. Version 1. Centre for Ecology and Hydrology, 1999. Natural Environment Research Council.

11.1.2 Field Survey Methodology

Site visits were carried out between July and August 2002, at the same time as habitat surveys were undertaken. Stream courses in forest plantations were examined, together with soils in roadside sections.

A further visit was made in May 2003 to inspect a well at Boganclogh Lodge (NJ436295) used as a private water supply. Surrounding environmental conditions were also surveyed and the impact of development on the water supply was discussed with the users of the well.

11.1.3 Significance Criteria

The significance of potential impacts has been assessed by taking into account the sensitivity of the baseline environment and the potential magnitude of the expected effect. Criteria for assessing the magnitude of the expected effect are given in Table 35. Impacts may be permanent or temporary, and may have a negative (detrimental) or positive (beneficial) effect on the environment.

Negligible	No perceptible changes to the hydrological or hydrogeological regime
Minor Significance	Some noticeable changes to the hydrological or hydrogeological regime
Moderate Significance	Material but non-fundamental changes in the hydrological or hydrogeological regime
Major Significance	Fundamental changes in the hydrological or hydrogeological regime

Table 35 Criteria for effect magnitude

The sensitivity of the receiving environment, together with the magnitude of the effect, will define the significance of the effect (see Table 36). The sensitivity of the environment to each effect was considered and assessed as being negligible, low, moderate or high.

Effect Magnitude	Sensitivity			
	Negligible	Low	Moderate	High
Negligible	Negligible significance	Negligible significance	Negligible significance	Negligible Significance
Minor	Negligible significance	Minor significance	Minor significance	Moderate Significance
Moderate	Negligible significance	Minor significance	Moderate significance	Major Significance
Major	Negligible significance	Moderate significance	Moderate significance	Major Significance

Table 36 Significance criteria

11.2 Existing Conditions

11.2.1 Rainfall

The wind turbines are to be sited on the western side of Clashindarroch Forest. The average annual rainfall of the area, based on Meteorological Office data for nearby settlements (1951-1980) is about 860 mm. The relief of the development site varies from 220m AOD (Above Ordnance Datum) in valleys on the east of the site to just over 500m AOD along the prominent western scarp edge of the Clashindarroch hills. Average rainfall within the development site is likely to be higher by about 50 mm as a result of altitude. Over the past four decades winter rainfall in the area has increased slightly, partly as a result of a higher number of days with heavy rainfall (>15 mm), whilst summer rainfall has declined slightly, a trend which is consistent with scenarios of man-made climatic change based on climate model simulations (Climate Research Unit, 2002).

11.2.2 Hydrogeology

11.2.2.1 Geology

The geology of the area comprises metamorphic bedrock overlain by glacial and alluvial drift deposits. Most of the development area is underlain by metasedimentary rocks (mainly semipelite) of the Clashindarroch Formation (Dalradian Supergroup), and a restricted area of serpentinite around NJ4229 which is entirely obscured by deep hill peat and till (see Figure 18). The glacial material is a thin boulder clay of variable depth, sufficiently deep to restrict bedrock outcrops to the highest ground.

The soils of the development site, including a map prepared before most tree planting, are discussed in Section 9. Materials are wholly acidic and relatively base-poor, with podzolic types extensive and blanket peat common on the highest ground. Steep valley slopes have brown earth soils and valley floors have surface water gleys and peaty gleys. There are a few small mapped areas of raised bog peat.

11.2.2.2 Hydrogeology

The principal potential aquifers within the study area will be within peat on the highest ground and in the alluvial and slope colluvial morainic deposits which are likely to be in at least partial hydraulic connection with local surface water bodies. The peat deposits are probably no longer saturated. Habitat survey suggests that past peat cutting was extensive and that peat on open ground is dominated by dry heath or dry forms of blanket bog vegetation. Most peat has been ploughed and planted with conifers and this too will have reduced the watertable height and overall volume.

The metamorphic bedrock is likely to have low permeability and groundwater flow will be dependent upon the degree of fracturing present. Much of the high ground is only likely to be a minor aquifer because the rocks will have a low intergranular permeability but higher fracture permeability (faults are present at approximately 700 metre irregular intervals on the three recently produced British Geological Survey maps covering the site).

Regionally, groundwater gradients are likely to mirror the topography. Within the site, groundwater flow directions are likely to follow surface run-off patterns, namely towards and along the streams. Almost all run-off drains eastwards.

Owing to the current land use (forestry) it is likely that the groundwater is relatively good quality and significant contamination of the groundwater is unlikely to exist. The water is likely to be soft and acidic.

11.2.3 Private water supplies

The houses at Bogancloch abstract water locally via pipes, and there is a single well at NJ4351029465. The well is cased in cylindrical concrete cylinders with 1.2 m external diameter, sunk to a depth of approximately 2.5 m. An overflow pipe is inserted close to the top of the structure and water offtake to the house occurs at about 1.3 m depth. The top of the well is located 6 m above a narrow (0.4 m wide) incised stream which shows a surface water gley soil in the bank section. The well lies below a steep slope which carries a forest road about 25 metres upslope, with a narrow clearing separating collapsed Lodgepole pine trees and poorly-growing Sitka spruce. Vegetation surrounding the well is strongly flushed and water supply is from below, fed more by flow downvalley rather than from the adjacent hillslope.

It is likely that the supply is entirely local, from within a local very small forested catchment. There is little water movement from upslope, probably due to soil groundwater interception by the forest track above the road. Former wet tussock grassland adjacent to a ditch at the side of the road has dried out, allowing dry ground species to form a carpet over old tussocks. This is good evidence for very minor water volumes moving downhill in the vicinity of the well. Further uphill still (NJ4343629704), above good Sitka spruce growth, a wide ride contains an old field boundary, and the remains of ditches diverting water to the west and east, away from the well to the south. Any pollution from the

development above would be rapidly intercepted and captured by tree roots, or diverted by drains away from the well.

11.2.4 Groundwater Vulnerability

The Groundwater Protection Strategy for Scotland [5] classifies the area as “*weakly permeable*”. This type is of generally low vulnerability.

11.2.5 Soil Hydrology

The dominant podzolic and organic soils types present in the Clashindarroch site reflect the prevailing cool temperatures and moderate annual rainfall in this location. However, the limited extents of brown earth mark the influence of bedrock close to the surface on steeper slopes and slope geomorphological processes. These produce well-drained conditions which contrast strongly with waterlogging in surface water gleys in valley floors below the slopes. The gleys are finer-textured, due to accumulation of silt and a little clay after removal by runoff from till materials on higher ground.

The soils of the area are mapped as Winter Rainfall Acceptance Potential (WRAP) Class 5, indicating long periods of surface saturation and high runoff coefficients. The distribution of soil types as mapped by the FCS is shown in Figure 28. The Soil Survey of Scotland maps the site as the Foudland Association, with three forms very similar to the types identified by the FCS: non-calcareous gleys, humus-iron podzols and peaty podzols with some brown forest soils (= brown earth) and gleys.

The deeper peat of the FCS survey is not well-reflected in the Soil Survey of Scotland mapping and extensive thicket-stage forestry at the time of survey might have obscured its importance on high ground. Peat soils are formed as the decay of organic matter in the soil is retarded due to frequent waterlogging and low temperatures. Two key parts are recognised in deeper peat soils in terms of hydrological behaviour. The acrotelm is the unhumified upper layer of peat (often only a few centimetres thick) which overlies the humified catotelm that comprises the majority of the peat depth. The acrotelm is relatively permeable and the water table will fluctuate between the soil surface and the base of the acrotelm. The catotelm generally has a much lower permeability and in undisturbed peat this layer will generally be fully saturated except in the driest periods. However, past peat cutting and a small amount of gully erosion have drained the thicker peats and lowered the watertable within the catotelm and the acrotelm has dry forms of blanket peat or dry heath vegetation.

It is likely that these site peat soils can hold considerable volumes of water (due to their high porosity), but their low permeability means that baseflows during summer periods may be very low as the rate of water movement through the peat (hydraulic conductivity) can be very slow. During wet periods, however, the peat will be saturated at or very close to the surface so that much of the runoff will occur as overland flow or near-surface throughflow, with runoff leading to high stream flows.

The other soils on site are typical of uplands and, although better drained than peats, may be expected to be waterlogged occasionally (most frequently in winter), with subsequent higher runoff volumes and rates.

Afforestation has altered site hydrology enormously over the past five decades. Many new drains were cut and ploughing downslope accelerated runoff and sediment movement. Streams within the site are still adjusting to change and show sections of incised downcutting alternating with areas of run-on where silts are accumulating and soft-ground vegetation is present. Many of the smaller streams are now obscured under tree cover and their ecology has changed completely. Tree litter has formed a thick needle layer over much of the ground apart from in wider rides. A mor-moder humus layer has developed, with better drainage characteristics than the peaty upper horizons of former podzols.

In summary, the soils of the site vary greatly in terms of drainage and have been much changed in preparation for, and following, afforestation.

11.3 Land Use

The site is managed by FCS as a commercial plantation, with secondary usage for recreation by the public. There are active and abandoned stone quarries present outwith the wind farm site.

11.3.1 Watercourses and Surface Water Catchment Areas

The site lies within several subcatchments of the River Deveron and it is these and the main catchment which potentially may be affected by the wind farm: the River Deveron flowing north on the western side of the development, various burns draining southeast in moderately steep-sided valleys towards Rhyndie, meeting as the Water of Bogie and then River Bogie, which drains north to meet the Deveron east of Huntly. The Deveron flows into the Moray Firth at Banff Bay (NJ6964).

11.4 Assessment of Construction Impacts

11.4.1 Potential Impacts

The most serious risk of significant impact is likely to be experienced during the construction period as this is the time when there is most activity on site. In addition to construction of wind farm infrastructure, a large area of standing forest will be clear-felled and a small proportion topped (all totaling about 720 ha) and this will affect the upper headwaters of all sub-catchments.

11.4.2 Impediment to flows

Temporary works and new permanent infrastructure may lead to a reduction in the hydraulic capacity of any watercourses that they cross. The proposed access tracks will use existing tracks but upgrading will be required and this will involve work crossing a large number of land drains, stream courses and a few peat hags on the highest ground. Work might impede flows within these. The water drainage currently provided by these features influences the soil moisture conditions around them, and this may, in turn, affect the ecological systems. Impediment of flows may lead to higher upstream water levels and increased flood risk upstream. This has been assessed as a potential impact of minor significance because of the existing extent of good natural drainage in the soils of the area, and the further improvements made in preparing the ground for tree production. The influence on ecology is likely to be negligible.

11.4.3 Impact on water table levels

Groundwater control may be required for some of the deeper excavations during construction of the turbine bases. Groundwater control measures may include physical cut-offs or dewatering by pumping. Dewatering will lead to temporary lowering of the water table in the area around the turbine bases. This may lead to base flows to nearby surface water bodies being affected, although given the scale and size of the turbine bases this will be insignificant. Dewatering of deeper peat may occur very locally but most such ground is already very dry and the ecological implications are minimal. The impacts of the dewatering on water flows are likely to be temporary in nature and overall dewatering effects have been assessed as being of minor significance.

11.4.4 Pollution Effects

A key potential construction impact is the effects of any pollution associated with construction traffic and chemicals. The likelihood of a pollution incident occurring in the area will be increased as the amount of foreign materials such as cement, fuel and oil, are brought to site.

Unset cement or concrete may enter a watercourse and cause a pollution incident. Similarly, a fuel spillage during refuelling or a fuel, oil or hydraulic oil leak during construction operations may also cause a pollution incident. Pollution may also occur from leakage of any chemical stored on site during the construction phase and could arise from the contractor's toilet facilities. Any such pollution incident may cause ecological damage or affect water quality at downstream abstraction points. These chemicals may also pollute soil and groundwater.

The watercourses which would be at the greatest risk of pollution are those situated closest to the potential pollution source; especially if the construction works are within the stream channel or flush zones feeding the streams. There are few actual watercourses within the wind farm site and use of

existing tracks will minimise crossing of small headwater streams and flushes. Given the nature of the soils in the area and the presence of plough lines, drains, some flush zones and gully systems, it is likely that any spillage would flow rapidly into a watercourse and thus the entire site should be treated as a sensitive area.

The on-site private water supplies southeast of the development are considered to be at negligible risk of pollution due to the effects of drains and road above it on the slope leading to the development, and the fact that it is sited above a small stream which probably does not contribute to the well supply.

Taking into account the size and location of the development an increase in the likelihood of pollution effects during construction has been assessed as a potential impact of moderate significance.

11.4.5 Erosion and Sedimentation

Sediment will be generated as the ground is disturbed during construction of the wind turbine bases, the access tracks and their associated drainage ditches. This could be caused by vehicles tracking over disturbed ground, excavating into the soil or possibly due to high organic matter and suspended solid loads within water pumped from the ground during temporary dewatering of excavations. This erosion may lead to deterioration of the soil quality and may cause ecological impacts.

The clear-felling of a large area of forested ground will remove a protective intercepting tree cover from a very large area, with machines possibly churning the ground surface and leaving a mix of brash and exposed soils. Existing plough lines and drains might then act as water conduits transporting soil materials and plant debris.

The sediment generated may be transmitted into local watercourses and transported downstream, causing high turbidity in the watercourses. As the gradient of the watercourse reduces further downstream the sediment may then be deposited, causing ecological changes in these downstream locations. This effect is locally common at Clashindarroch as a result of drainage operations as part of forest management. There is unlikely to be any affect upon adjacent SSSIs because their drainage is hardly within the wind farm clearfell area and site roads are entirely outwith the SSSI sub-catchments. The proposed northern access will involve some road widening and runoff during the construction phase will be passed through silt traps to avoid contamination of waters lower down the catchment.

An increase in erosion and sedimentation during construction (including clearfelling) has been assessed as a potential impact of moderate significance.

11.4.6 Compaction

Construction traffic may cause compaction of the soil over which it travels. This may reduce the permeability of the ground and disrupt natural flowpaths. It can have an especially large impact in areas of peat as most hydrological activity takes place in the upper few centimetres of the soil profile. Compaction of the soil may lead to a reduction in infiltration rates, disruption of lateral subsurface flowpaths and increase in erosion due to surface runoff.

Compaction of the soil has been assessed as a potential impact of moderate significance.

11.4.7 Proposed Mitigation Measures

A number of mitigation measures will be implemented during the construction to minimise the hydrological effects of the proposed development. These take account of published guidance by SEPA (1999) and, especially, the guidance offered by the FCS (1998, 2000) in Forests and Soil Conservation and Forest and Water guidelines. These mitigation measures include:

- Watercourses will not be blocked or equipment, materials or chemicals stored near them;
- Drip trays will be placed under standing machinery to avoid oil and petrol pollution during oil changes and maintenance operations
- If fuels and lubricants are stored on site during the construction period, they will be contained within a properly designed bunded area to reduce the risk of spillage.

- All fuel oil will be stored in a bunded area that is drained through oil interceptors and which meets the requirements of the Groundwater Regulations, which are enforced by SEPA. This is only necessary if the bunded area is drained, as many bunded areas are enclosed to keep out water etc and contained spillages are within another tank.
- All repair and maintenance work to plant and vehicles will be within bunded areas, drained through oil interceptors, which meets the requirements of the Groundwater Regulations, enforced by SEPA.
- The storage and use of any chemical additives used during construction, such as plasticisers in mortar and concrete, will be subject to the same precautions as fuel oils.
- Cement and unset concrete will be kept out of watercourses during construction as they are highly toxic to stream life.
- Contingency plans and equipment will be in place in case of an uncontained fuel spillage.
- Peat cut during construction of the tracks will be reinstated as soon as practicable to minimise the risk of desiccation of cut peat turfs and erosion of exposed surfaces.
- Any sediment generated during construction will be treated in such a manner that it does not enter the local watercourses. This will include the provision of a large number of silt traps and settlement ponds, located to intercept suspended solids moving via the extensive drainage ditches in the forest area.

As a minimum, the following sources of guidance published by SEPA will be followed:

- Pollution Prevention Guidelines (PPG) 1: Prevention of Pollution of Controlled Wastes
- PPG2: Above Ground Oil Storage Tanks
- PPG5: Works in, Near or Liable to affect Watercourses
- PPG6: Working at Construction and Demolition Sites

Work in the clear-felled areas will follow FC Forest and Water Guidelines for harvesting, including:

- liaising with SEPA at the planning stage;
- ensure all operators have and understand contingency plans;
- locate, sign and protect the on-site private water supplies by keeping all traffic off the road above the well site;
- operations managed to ensure that ground damage and water run off is prevented by the appropriate use of brush mats, harvesting systems and suspension of operations periods during and immediately after heavy rain fall
- protecting underground culverts;
- avoiding skidding on soft soils and ensuring maximum use is made of brush mats for temporary timber extraction routes and as much soil protection as possible;
- selecting dry sites for stacking and loading timber;
- planning to minimise stream crossings;
- use pipes for all water crossings;
- avoiding long extraction routes on steep ground;
- forbidding the use of machines in streams;
- felling trees away from streams but maintaining a buffer zone around watercourses, designed to intercept all sediment and prevent it reaching any watercourse;
- keeping all plant material (tree branches and tops) out of streams to avoid blockage of culverts;

11.4.8 Residual Impacts

There will be some residual impacts associated with the construction effects of the wind farm as discussed above which may include:

- local reduction in the water table from dewatering during construction;
- reduction in the permeability of the ground and disruption of the natural flowpaths from compaction;
- pollution of watercourses.

If the construction is planned and undertaken with care following the mitigation measures identified above, all of the impacts described will be insignificant, except for pollution. If pollution during construction was to occur it could potentially have a significant effect. However if the mitigation measures are implemented, the likelihood of occurrence is minimal.

11.5 Assessment of Operational Impacts

11.5.1 Potential Impacts

11.5.1.1 Modification to drainage patterns

The foundations of the wind turbines may intercept and alter the nature of the shallow aquifers on the site. The depth of foundations may be significant in terms of the thickness of a peat soil and its aquifer, and the depth of the groundwater circulation, given that the underlying bedrock is of low permeability. In places it is likely that the foundations will completely penetrate the drift or peat. However, the limited lateral extent of the deep foundations is unlikely to significantly affect the groundwater flow paths. Given the small fraction of the area affected by the turbines and the fact that the wind farm is not located near any known water abstractions, any impacts due to the wind turbines will be insignificant.

Roadside drains may intercept natural drainage depressions and channels, also disrupting natural drainage patterns. This can lead to changes in drainage areas, reducing flows into one stream while increasing flows into another, and thus changing the volume of runoff in a stream.

Existing roads will be used, but even so, new tracks will need to be built and a limited amount of roadside drainage may be required which might disrupt natural drainage patterns.

Based on the topography of the area, it is considered that this impact would be minor as the potential for diversion of drainage from one stream catchment to another is limited, significant lengths of track drains are unlikely to occur and the density of existing drains and gullies is such that new drainage will not cause a large change to the baseline conditions.

11.6 Impact on water table levels

Potential drawdown effects on the water table may be caused by the installation of roadside drains, due to an increase in local hydraulic gradients within the soil. These impacts may cause the water table in the soil around the drains to be lowered. This effect is already present adjacent to some forest roads.

The presence of turbine bases and access tracks may cause local alterations to natural flow pathways immediately around the track. This may lead to a reduction in water flow from upslope if the track drainage alters existing hillslope flow patterns.

These effects are likely to be limited and localised due to the moderate permeability of the soils and relatively steep slopes surrounding any drain. However, given the sensitivity of peat to other factors (such as settlement and exacerbated erosion) this potential impact should be regarded as being of moderate significance.

11.7 Runoff Volume and Rates

An increase in runoff could occur due to an increase in impermeable areas such as tracks and turbine bases. At the site it is predicted that minor changes in runoff volumes would occur, particularly as the current hydrological regime is such that surface runoff will be common across the site under existing conditions. The area of the concrete turbine bases is negligible compared to that of the catchment areas, while the new tracks, which themselves make up only a small proportion of total catchment area, are to consist of relatively permeable stone and geotextile. The development is therefore likely to have a minor impact on the volume of runoff and baseflow generated from the site. Given the very small relative area taken up by the tracks and turbine bases, an insignificant impact on recharge to groundwater would be expected.

The installation of a road drainage system could have a noticeable impact on runoff rates and natural catchment areas, if not designed properly. A road drainage system could increase runoff peaks in watercourses immediately downstream of the site as the transfer of water from the hillsides into stream channels would be much more efficient, allowing more rapid runoff response.

Given the topography of the site and the low proportion of the catchment areas affected, plus the amount of drains and gullies currently present across the site, it is expected that this would have a minor impact on runoff rates and therefore flood risk.

11.8 Pollution Effects

During operation the same potential impacts, as described for the construction phase, are present although the likelihood of these impacts occurring are much lower. During operation, vehicles will visit the site to carry out routine maintenance and emergency repairs. Therefore, the impact of any pollution event will remain the same and must be considered to be of moderate significance.

An additional pollution risk may be associated with sulphate attack of the concrete wind turbine bases, leading to alkaline leaching into groundwater. This is likely to be highly localised around the turbine bases and will have an insignificant impact on the general groundwater quality of the area.

It is not proposed that pesticides or herbicides will be used during the operation of the wind farm.

11.9 Erosion

Soil erosion may occur wherever flows are artificially concentrated, especially in areas where soil is disturbed. The obvious area where this may occur is within drainage ditches, and on disturbed soil adjacent to ditches in the clear-fell area. Exposed soils will also become more prone to freeze-thaw action, which will again increase erosion rates. Erosion of the track material itself may also occur if the track is poorly designed or the wrong material is used. Erosion may also occur around culverts crossing watercourses, drains and gullies if these are not correctly designed. These impacts will be especially important in areas of high slopes where erosive forces are higher. Due to the degree of erosion currently occurring at the site as a result of past forestry establishment methods, some sediment will be present in the streams during storm events and therefore the site will have a moderate sensitivity. The introduction of access tracks and associated drains of limited length may have a minor effect on erosion rates at the site, resulting in an impact of minor significance.

11.10 Fluvial Geomorphology

Changes in flow and sediment volumes could affect stream geomorphology. The impacts are various and could include increased erosion of stream banks in steep areas and downstream sedimentation. Any bank protection works required to protect the access track from erosion will have an impact on fluvial geomorphology. Given that the proposed layout would have a minor impact on the flow and sediment regime of the area, a minor impact on stream geomorphology is also anticipated.

11.11 Proposed Mitigation Measures

A number of mitigation measures will be implemented during the design, and operation of the scheme to minimise the hydrological effects of the proposed development. These measures include:

- The access tracks will be constructed of inert material of suitable grade to withstand the expected traffic loading. If incorrect materials are used ruts may form which will reduce infiltration, provide preferential flowpaths and erode rapidly. The track will be constructed of coarse material if possible, to maximise infiltration through the track. This will reduce surface runoff on the track itself, reducing the risk of erosion and pollution.
- Roadside drainage will be avoided where possible and where it is required roadside ditches will be designed to affect the natural hydrology as little as possible. It is envisaged that roadside drains will be provided only on the upslope side of cut tracks.
- Depths of the ditches will be kept to the minimum required for free drainage of the track.
- Individual drain lengths will be kept to a minimum to avoid significant disruption of natural drainage patterns and avoid accumulation of large volumes of water within an individual drain.

The relevant forestry guidelines recommend that land drains are no longer than 30 m in length under normal gradients, plus cross-drains at appropriate (much longer) intervals. A reduction in drain length also reduces pollution risk. Regular cross-drains will be placed in the track surface, especially in high gradient areas, to prevent significant flows occurring on the track surface. Drain lengths will be shortened in high gradient areas and bars placed across the track to avoid accumulations of large volumes of surface water.

- Drains will not discharge directly into a watercourse but will flow out into a buffer zone which will act as a filter strip, often with a sediment trap to intercept suspended solids. Buffer zones are used to allow infiltration of water and reduction of runoff velocities. This reduces the flashiness of response, encourages deposition of sediments and allows pollutants to be filtered out. It is vitally important that the risk of pollutants entering the flush zone and stream channel system be minimised. Flow within these upland streams is rapid and turbulent, making containment of pollution once it has entered the stream channels extremely difficult.
- Where appropriate, a cut-off drain will be installed at the top of the track cutting to control seepage from natural ground into the cut.
- Pesticides will not be used to maintain the access tracks.
- Alkaline leaching from the turbine bases will be minimised by using a concrete mix designed to withstand sulphate attack, as detailed in the code of practice for concrete design BS5328. Sulphate resistant concrete will be used where appropriate in the construction of all turbine bases, reducing sulphate attack effects to a negligible level.
- Culverts and drainage pipes will be laid beneath the track whenever it crosses a flush zone, drain or gully to avoid disruption of natural drainage. Culvert inlets and outlets will be protected to avoid erosion.

11.12 Residual Impacts

Even with the above mitigation measures there will be some residual impacts associated with the operation of the proposed wind farm. However, if the wind farm is designed and operated with care following the mitigation measures recommended above, all of the impacts described above should be insignificant, except for pollution effects. If pollution during operation was to occur it could potentially have a moderately significant effect. If the mitigation measures are implemented, the likelihood of occurrence is minimal.

11.13 Future Monitoring Requirements

The impact of the wind farm on the hydrology of the area will be reviewed as part of the maintenance regime. A residual inspection of the tracks, drains, sediment traps and surrounding land will be undertaken on a regular basis to ensure that the wind farm is not subject to, or causing, erosion, drying out of surrounding land or flooding.

11.14 Future Situation Without Scheme

If the scheme did not go ahead it is likely that present processes would continue in the near future, particularly erosion and sedimentation as a result of past afforestation methods on some steep slopes.

11.15 Summary of Impacts

Table 37 summarises the impacts relating to the construction period.

Potential impact	Significance	Mitigation	Residual impact
Impediment to flows	Moderate	Appropriately-sized culverts will be used	Insignificant
Impact on watertable levels	Minor	Drain depths will be limited	Insignificant
Pollution effects	Moderate	Good working practices will be adopted and pollution response plans prepared	Minor
Erosion and sedimentation	Moderate	Erosion prevention measures will be planned; sediment traps and buffer zones will be used	Minor
Compaction	Moderate	Good working practices will be adopted	Insignificant

Table 37 Summary of construction impacts

Potential impact	Significance	Mitigation	Residual impact
Modification of drainage patterns	Minor	New drain depths and lengths will be minimised	Insignificant
Impact on watertable levels	Moderate	New drain extents and depths will be minimised	Insignificant
Impediment to flows	Moderate	Appropriately-sized culverts will be used	Insignificant
Runoff volumes and rates	Minor	Impermeable areas and new drain lengths will be minimised	Insignificant
Pollution effects	Moderate	Good working practices will be adopted and pollution response plans prepared	Minor
Erosion and sedimentation	Moderate	Erosion prevention measures will be planned; sediment traps and buffer zones will be used	Minor
Fluvial geomorphology	Minor	Erosion will be minimised	Insignificant

Table 38 Summary of operation impacts