Archimedean screw
Hydropower installation at
Guyzance Meander

Designer's Risk Assessment

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Introduction

The Construction (Design and Management) Regulations 2015 (CDM 2015) require that design should avoid foreseeable risk to health and safety of any person constructing, maintaining or working in the designed construction or liable to be affected by construction (§11.3). Hazards may be eliminated by design, risks arising from all hazards must be reduced where possible by design decisions, identified risks must be enumerated in information provided to clients and contractors so that remaining risks may be controlled (CDM 2015 §11.4/6).

CDM furthermore requires designers and others to satisfy themselves of their own competence and of that of their subcontractors to fulfil their duties under CDM; and to co-operate with other parties to reduce risk, including reporting any new risks which emerge.

This document presents the designer's formal consideration of the health and safety factors of the proposed design (CDM 2015 §11.6) resulting in the "reasoned and professional decisions" underlying that design (CDM Approved Code of Practice p.32). Assessment follows the category scheme favoured by the Health & Safety Executive, with reference to CDM where appropriate. In accordance with the regulations, this document will not consider hazards and risks which are generic to construction design or to the ensuing construction activity, but will instead limit itself to "specific and unusual" risk within the project "which may not be obvious to contractors" (ibid).

However there are other important potential risks from hydropower projects which lie beyond consideration of human health and safety, namely risks to the natural environment and the social risks of potential impacts on flood risk and drainage. For completeness, this document therefore also starts out with an assessment of these environmental risks and how they are addressed by this project.

Under CDM, the client accepts a duty to provide the designer with Pre-Construction Information detailing any known hazards of the site. These will only be reiterated in the present document where they illustrate such "specific and unusual" issues.

Archimedean screw hydropower systems

CDM requires adoption of general “principles of prevention” (MHSW 1999), espousing risk reduction via collective means and adaptation to technical progress. Health and safety assessment should therefore also acknowledge that the installation of efficient renewable energy systems in and of itself acts to reduce risk to the public and to individuals, by displacing combustion-based generation and the public hazard of atmospheric emissions.

A hydropower scheme relies upon diverting moving water down a fall in the landscape via a turbine to generate electricity. In this context, it is necessary to tolerate and/or mitigate certain hazards which elsewhere might be eliminated by design: the presence of rotating machinery, electrical cables and equipment, flowing water, and a change in ground level.

In the case of the Archimedean screw turbine, this equipment type is recognised by the Environment Agency (in England & Wales) as the forefront of “sustainable” hydropower in that it poses potentially low impacts to river ecology. While some ecological benefits may also be transferable to human health and safety, the imperative to exploit this preferred technology does impose some technical constraints (e.g. in scale and layout), such that certain hazards must be mitigated rather than eliminated. These details are enumerated in the present risk assessment.

Hazard categories

Harm to the environment

Hydropower schemes are built in the river environment, either beside or in rivers. Rivers are a sensitive part of the natural environment, in terms not only of locally-resident habitat but also of connectivity – both for the movement of species and for the onward provision of water, oxygen, sediments, gravels and woody debris to areas downstream. The present scheme has considered and addressed all of these potential areas of impact, as detailed in the submission documents (for detail, see document entitled Environmental Sustainability Assessment (ESA)). Namely:

- Potential pollution of the watercourse and landscape
    - during works, is to be avoided through prevention and mitigation measures described in contractors' Construction Method Statements in accordance with GPPs for in-river works (or other current successor to PPGs). These MSs are required from contractors when the contract is offered. Measures must include e.g.: flood-proof bunding of fuels/oils and secure storage of all materials outside the flood plain, checking that plant does not leak, maintaining spill kits on site, washing of plant between sites, dewatering cofferdams only via silt traps, minimising tracking in the river, casting/setting to occur only within dewatered cofferdams and not when high flows anticipated.
    - during operation, is to be avoided through flood-proof secure storage of all materials in a watertight powerhouse, with spill kit provided in contract and to be maintained by operator. All lubricants used in operation to be vegetable-based or equivalent alternatives such as PANOLIN products.
- Potential spread of invasive species, where present, is to be managed by standard prevention and mitigation measures described in contractors' Construction Method Statements in accordance with GPPs for in-river works (or other current successor to PPGs) for legally required disposal, with personnel awareness to be maintained via toolbox talks.
- Potential harm to river habitats and species, including features of interest of the SSSI designation
    - due to changed water flow routes during operation of the scheme, has been assessed by hydromorphologists and ecologists whose reports have influenced the design. These reports are submitted in full with the

consenting application, and found broadly that the scheme as proposed is low-risk. Consequently, mitigations which are likely to be agreed acceptable by the EA have been incorporated in design, which include:

- Proposed flow regime limited to a Q75 minimum residual flow and thereafter a 50% proportional take – a regime which poses lowest risk to all receptors
- Use of an Archimedean screw turbine, with coarse debris screening, which retains the use of the abstracted water as a movement route for biota, small debris and sediments
- Relationship of turbine outflow in relation to onward river channel is designed to minimise attraction to migrating fish
- Potential to incorporate improvements to lamprey and/or eel passage

  - due to passage through the turbine, during operation of the scheme, is minimised by standard EA mitigation measures for Archimedean screws, in the light of the balance of latest scientific evidence. If the evidence is such as to indicate that there is an unacceptable level of risk, and that the EA must therefore prevent certain fish species from passing through a screw turbine, the EA is able to impose screening requirements to achieve this. This has not been the case to date: the EA has accepted that the evidence does not support a significant risk, and the EA in its licensing decisions has thus far created no precedent for imposing fish exclusion screening of Archimedean screws, so it is not proposed. Standard mitigation methods will be adopted, including compressible rubber bumpers on the blade leading edges, blade edges set back from the trough edge, rotation speed (RPM) and dimensions within the EA guidance matrix for these factors. Over and above EA guidance, a variable-speed control system and a steel trough are specified, as these ensure a deeper water column and a smooth surface (respectively), which are seen as likely to minimise risk for fish.

- Potential risk to hydromorphology, due to changed water flow routes during operation of the scheme, has been assessed by hydromorphologists whose report has influenced the design. This report is submitted in full with the consenting application, and found broadly that the scheme as proposed is low-risk. Consequently, mitigation likely to be agreed acceptable by the EA have been incorporated in design, namely:

- Proposed flow regime limited to a Q75 minimum residual flow and thereafter a 50% proportional take – a regime which poses lowest impact while still allowing a viable scheme
- Use of an Archimedean screw turbine, with coarse debris screening, which retains the use of the abstracted water as a movement route for biota, small debris and sediments

Flood risk

Hydropower schemes are built in the river environment, either beside or in rivers, as water-compatible development. Through both the Planning Process and the Environmental Permitting process, new schemes must demonstrate that they will have no unacceptable impact on flood risk. The present scheme has considered and addressed flood risk in the submission documents (for detail, see document entitled Flood Risk Assessment (FRA)). Namely, the development:

- in itself is water-compatible and designed to be resistant or resilient to above predicted flood levels
- does not create a net obstruction to river flow or flood flows
- does not raise water levels or spill levels
- requires no temporary works which occupy more than a small fraction of the river channel cross-section (cofferdams close to the bank line only)
- does not affect flood risk or detriment to other receptors

Drainage impacts

Hydropower schemes involve the diversion of water through a different route. As such, they have potential to detrimentally impact how water from other sources currently drains or escapes, or how water discharges are diluted. The present scheme has considered and addressed both of these potential impacts, as detailed in the submission documents (for detail, see documents entitled Flood Risk Assessment (FRA) and Environmental Sustainability Assessment (ESA)). Namely:

- The area of new or changed physical works does not contain drains which could be crossed or interrupted by the works
- The new or changed works do not form a barrier to surface water movement
- The new or changed works do not (and cannot physically) raise water levels, so cannot prejudice free drainage from any existing drains to the watercourse
- The new or changed works do not create any new source of drainage or waste discharge. (NB: Water is let through the scheme under an abstraction licence and

is returned unconsumed to the river, which requires no discharge consent. The end-to-end operation occurs under the terms of the abstraction licence.)

- Operation of the scheme will marginally lower water levels within the depleted reach of the river only, within agreed limits which are set to eliminate a risk of unacceptable low flows. Local discharges are small or into distant tributaries, and are therefore not at risk from this marginally reduced dilution.

Falls from a height

The greatest cause of construction fatalities, fall hazards must be addressed in design. Powerhouse design aims to minimise the scale of the structure, subject to functional considerations and the aesthetic requirements of local planning. Although wall height is typically only a single storey, planning requirements may necessitate a pitched roof and may constrain its surfacing material, fall protection, and orientation. Design should ensure that steps and platforms where provided at height are guarded appropriately and that windows where provided may be cleaned effectively with minimal risk of falling. Where design necessitates open channels, their banks should be guarded appropriately to their scale as a hazard and to the degree of risk (depending e.g. on accessibility) at the site in question. No other hazards are identified which are not generic to design and construction.

Slips, trips and falls

It is usually undesirable for design to aggressively engineer the riverside environment to eliminate hazards which are inherent in the natural topography of such sites. Design does however seek to reduce risk in terms of the prudent routing of cabling, positioning of handrails, and surfacing of walkways, steps and platforms where these are provided. Powerhouse design includes consideration of floorspace and surfacing appropriate to operational use. During construction, risk is minimised by the appropriate use of platforms, ladders, dewatered cofferdams/bunds, and the adoption of Clean Site Policy in contractors' method statements. No other hazards are identified which are not generic to design and construction.

Asbestos

No hazards are identified which are not generic to construction activities. In CDM projects, the management of any asbestos declared to be present in the client's Pre-Construction Information will then be articulated within Construction Method Statements.

Chemical & Biological Exposure

Chemicals: While design cannot eliminate the use of cementitious materials, petro- and other chemicals which may be used by contractors in the course of construction, the use of cement is kept to the structural minimum and alternatives preferred where feasible. Cement use is reduced by the design choice of an Archimedean screw over the closest comparable turbine design type (Kaplan), as the former is installed at less depth with its upper side open to air. Potential contamination of the watercourse as a pathway for chemical risk is to be avoided through prevention and mitigation measures described in contractors' Construction Method Statements in accordance with GPPs for in-river works (or other current successor to PPGs). In terms of substances used in operation (lubricants), environmental protection prescribes the use of vegetable-based or equivalent alternatives such as PANOLIN products which consequentially reduce human health risks.

Biological toxicity: Design of riparian structures must acknowledge minor health hazards from vegetation which may be present in riparian environments. Hands, arms and legs should remain covered when cutting or handling giant hogweed and herbaceous material in general (freshly cut hay, weeds among trees). Bracken spores may be harmful if inhaled: face masks should be worn when working among bracken during its sporing season (July-September).

Pathogens: Weil's Disease (leptospirosis) may be present in river environments and in rat and cow urine. Precautions should include avoiding ingesting river water, using waterproof plasters, washing hands before eating or smoking, and wearing waterproof boots to exclude water. Lyme Disease may be contracted from ticks, therefore skin should be covered when working in tall vegetation.

No other chemical or biological hazards are identified which are not generic to construction. For any "significant" health hazards identified, **CDM requires the contractor to submit proportionate formal instructions.**

Noise

Continuous noise levels are expected within the powerhouse during operation, with noise from the generator having been rated at 69dB. The regulatory threshold range is 80-87dB. Discontinuous peaks of noise are not foreseen. If noise levels arise within the powerhouse which make conversation difficult, operatives should utilise hearing protection during exposure which will adequately address the risk. Further risk reduction by design would be disproportionate, as the powerhouse is normally unoccupied, and its use as a workplace is infrequent and brief, except in cases where the noise-producing operation has been

suspended. Operation does not create dangerous levels of noise outside the powerhouse. No other hazards are identified which are not generic to construction processes, e.g. piling.

Vibration

Operation per design should not give rise to hazardous vibration. The only foreseeable circumstances would be under conditions of an electromechanical or mechanical fault. In this case the only individuals entering into the area of risk would be doing so with the objective of immediately stopping operation, removing the hazard. No other hazards are identified which are not generic to construction processes.

Electricity

Electrical installation: The electrical system is designed to G59 or G83 standards to allow safe installation and connection by a competent electrician and safe operation by following the client instruction manual.

Existing power lines: **Where high-voltage power lines are nearby, and for all complex lifting operations, CDM requires the contractor to submit proportionate formal instructions. Tree work in the vicinity of overhead power lines should be carried out according to HSE procedural guidelines on this activity.**

No other electrical hazards are identified which are not generic to design and construction.

Work equipment and machinery

In CDM terms, the scheme designer represents not only subcontracting designers but also any foreign designer of bespoke equipment (CDM 2015 §12), which in the present case includes the manufacturer of the turbine. The designer has selectively chosen equipment manufacturers from among their competitors, based on experience of design quality and safe service as well as standards accreditation. The intake screen, sluice and screw together with applied mesh guards or fencing, and security of the powerhouse or control boxes, are designed to provide an appropriate level of protection against accidental or wilful entry into the system during operation. Similar protection for a fish pass may be justified where there is a risk of public access. Upon handover the client must accept responsibility for maintaining these protective measures incorporated in the design, and for following precautionary procedures when scheme maintenance necessitates removing any protection. No other hazards are identified which are not generic to the plant and tools used in construction.

Maintenance and building work

Minimising intervention: Specification of an Archimedean screw turbine contributes to a reduction in maintenance footfall. It is both mechanically robust and obviates fine screening, increasing the intervals between service visits and screen-cleaning operations.

Water hazards: Proximity of water is unavoidable. Use of cofferdams as per method statements, inspected prior to work as per CDM, reduces water-related risks during construction. Design (depth, profile, velocity) of new channels is functionally driven. However, risk of falling into open channels may be eliminated by the use of pipes or culverts in cases where this alternative is considered acceptable by the regulatory authorities on ecological and other grounds. Fencing of open channels can mitigate risk. If there is risk of falling into >1m deep or fast-flowing water, or in the case of a contractor engaging in diving operations, CDM requires the contractor to submit proportionate formal instructions including procedures and the use of PPE. Particular risk arising from flood behaviour at the site is assessed separately in the course of gaining licences, consents and planning permission from the regulatory authorities. This risk is not considered to be significant in operational safety terms, as the system is unlikely to be attended (maintained, or operable) during hazardous flood levels.

Lifting operations: The screw turbine is necessarily large, requiring complex lifting in potentially uneven terrain with limited accessibility, near water and often near power lines. **CDM requires the contractor to submit a formal lifting plan proportionate to the complexity of the lifting operation.**

Groundworks etc: Design requires excavation in locations which are subject to the action of water. Design of excavations will involve support by piling, by the Introduction of formed concrete or masonry protection, or by sloping channel profiles appropriate to the nature of the ground. The extent of excavation and concrete forming is reduced by the design choice of an Archimedean screw over the closest comparable turbine design type (Kaplan), as the former is installed at less depth with its upper side open to air. For excavation at depth or in unstable or contaminated ground), for structural alterations or demolition of existing structures, and for any "unusual working methods**", CDM requires the contractor to submit proportionate formal instructions.** No other hazards are identified which are not generic to design and construction.

Workplace transport

Design includes consideration of providing appropriate vehicular access to the scheme once in operation. In the case of flood-prone locations, intermittency of operational access

must be recognised and due risk assessment carried out by operatives. Seasonality of access and ground stability are also considerations in the construction phase, and these must be treated in the construction timeline and method statements. Selecting appropriate plant is a matter for the contractor, but the design may recommend the use of particular plant for the delivery and mounting of equipment in cases where difficulty is foreseen at design stage. Any decision to use transport by water requires further assessment of water-specific risks. No other hazards are identified which are not generic to site transport.

Pressure systems

Design choice of an Archimedean screw turbine, working at atmospheric pressure, obviates the use of pressure pipework or syphons in conducting water. Where hydraulic actuators are used in the operation of intake sluice gates, their failure would result in system shutdown, with a negligible likelihood of risk to human safety. No hazards are therefore identified which are not generic to design and construction.

Fire and explosion

No hazards are identified which are not generic to design and construction, e.g. buried gas services. While it is conceivable that a fire may start during scheme operation, the context is a low-risk one, consisting of largely non-flammable materials and flowing water in a location isolated from other properties. As the most likely foreseeable causes are vandalism or a fault in electrical or friction systems, the hazard of a fire developing uncontrolled is greatest when the site is unattended, and the risk to safety is therefore low. The scheme itself does not make use of explosive materials. Use of blasting explosives by a contractor in the construction phase is not subject to specification within design: this would be subject to the contractor's own risk assessment and indeed CDM requires the contractor to submit proportionate formal instructions.

Radiation

Scheme design is not foreseen to pose an increased risk of exposure to ambient radon, even in high-radon areas, as the enclosed space to be created as a result of design is likely to be accessed only by constructors and operators for very limited and occasional periods. No other hazards are identified which are not generic to design and construction.

Musculoskeletal disorders

Design staff have been instructed in correct working posture. PC-based monitoring facilities requested as an option by some clients are unlikely in themselves to pose an increased risk over other work activities, as they will be accessed only intermittently. Manual handling methods and correct postural execution of other work activities are not subject to specification in design. No other hazards are identified which are not generic to design and construction activities.

Display screen equipment

Design staff have been instructed in correct use of DSE. PC-based monitoring facilities requested as an option by some clients are unlikely to pose an increased risk as they will be viewed only intermittently. No other hazards are identified.

Stress

Unacceptable stress experienced by the design team may be addressed by escalation of problems to the managing director. The design company encourages a climate of openness and mutual assistance among employees, while placing an expectation of professionalism on employees and on other professionals with whom they interact. Unacceptable stress experienced by contractors and subcontractors as a result of design should be resolved by communication with the project team. No other hazards are identified which are not generic to design and construction.

Regulations cited and held in consideration

CDM 2015: Construction (Design and Management) Regulations 2015
MHSW 1999: Management of Health and Safety at Work Regulations 1999
PUWER 1998: Provision and Use of Work Equipment Regulations 1998
LOLER 1998: Lifting Operations and Lifting Equipment regulations 1998
Health and Safety (Consultation with Employees) Regulations 1996
RIDDOR: Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
Supply of Machinery Safety Regulations 1992 (CE marking)
Health and Safety (First Aid) Regulations 1981
Safety Representatives and Safety Committees Regulations 1977
Health and Safety at Work etc Act 1974.
Employers' Liability Compulsory Insurance Act 1969

Other standards consulted in establishing design practice

Managing Health & Safety in Construction: CDM 2015 (HSE L153)
BS5304 2005 – Guidance on Safe Use of Machines
BS5395 – Stairs Ladders & Walkways
BS60439-5 1996 Specification for low voltage switchgear and control assemblies
WIMES 3.01 Water Industry Electrical Specifications
Lloyds approved welding procedures
IS09001 Manufacture
CE Certification
17th Edition Electrical regulations
G59 Electrical Grid Connection
HSE guidelines on arboriculture & power lines