Annex A

Construction Industry Research and Information Association paper, C763, River weirs – Design, maintenance, modification and removal, 2016, Chapter 10: Operational Safety

10 Operational safety

10.1 INTRODUCTION

This chapter discusses the operational safety of weirs, the hazards due to weirs, methods of risk assessment and how to mitigate the risks, either by design or retrofitting. It does not cover construction safety, which is not within the scope of this guide.

The hazards due to weirs can be hydraulic, physical, chemical or biological. The greatest hydraulic hazard is the strong re-circulating currents downstream that often look harmless because the water surface is relatively flat, and aeration of turbulent flow which reduces buoyancy and suction currents into sluices and by-washes. Weirs, or low-head dams, are known as 'drowning machines' in the USA and sadly, weir-related incidents result in one or two deaths per year in the UK. In the USA, 191 people are known to have died at weirs between 1970 and 2010.

Weir owners have a duty of care to authorised, unauthorised and accidental visitors and should manage the safety risks caused by a weir as far upstream and downstream as they have property rights. Beyond this, the weir owner should assess any specific locations where the hazards are known by the owner to result directly from the weir operations, and inform other affected property owners of the known hazards associated with the weir and its operations. Often there are conflicting demands on weirs and their owners, and a weir that meets functional objectives may present a safety hazard and difficult rescue conditions (**Figure 10.3**).

Guidance on risk assessment is given in **Section 10.2**. If the risk posed by a weir is unacceptable, it can be mitigated by eliminating or reducing the hazard, reducing the likelihood of harm or facilitating rescue (**Section 10.3**).

10.2 RISK ASSESSMENT

10.2.1 Overview

A risk assessment should identify the hazards at a weir, the people who may be harmed and likelihood of them coming to harm, and the ease of self or assisted rescue if they get into difficulty. A list of hazards due to weirs is given in **Table 10.1**.

Those affected can be water or land-based, eg operation and maintenance staff, boaters, canoeists, swimmers, anglers and walkers, particularly those affected by alcohol or drugs, and young people who use a weir or sluices for recreation without appreciating the hazard. The groups affected by hazards are not always obvious as recreation activities often take place outside working hours and may be seasonal. The full range of flow and tailwater conditions should be considered as the hazards and ease of rescue may be different under certain conditions.

A risk assessment should be reviewed periodically, with more frequent assessments if there is a serious incident or accident, if there are changes to the site or before works such as design, maintenance, operation and removal.

10.2.2 Hydraulic hazards

The greatest hazard due to weirs is hydraulic. The recirculating flow (hydraulic jump, hydraulic, stopper, towback or roller) at the base of the weir can prevent a floating object such as a person, dog or canoe from escaping. The person or object is repeatedly dragged underwater at the base of the weir, carried downstream underwater, back to the surface, only to be dragged underwater at the weir toe again, eventually leading to exhaustion and drowning. Aeration of the flow decreases buoyancy, making it hard for the victim to stay afloat.

The hazard depends on the weir flow type and the relationship between tailwater depth and the sequent depth of the hydraulic jump. Four cases can be identified as shown in **Figure 10.1**.

Hydraulic hazards may be determined from photographs of historic flood events or knowledge of the hydraulic behaviour of similar weirs. If this is not possible, then hydraulic assessment, numerical or physical modelling may be required.

Table 10.1 List of hazards due to weirs

Type	Hazard	Consequences
Hydraulic (Section 10.3.2)	Deep water downstream of weir	Drowning
	Submerged hydraulic jump at toe of weir (Figures 10.1 and 10.2)	Drowning
	Aeration leading to loss of buoyancy	Drowning
	Strong currents, particularly at sluice gates	Drowning
	Strainers and excessive seepage paths through dams	Entrapment and drowning
	Open spillways not visible from upstream (Figure 10.3)	Unintentional passage over weir and drowning
	Sudden changes in flow depth or conditions downstream of movable weirs	Drowning
	Breach of weir leading to flooding	People swept over by deep or fast flows, drowning, illness
Physical (Section 10.3.3)	Submerged hazards (difficult to spot, especially if turbidity affects visibility)	Foot entrapment and drowning, or puncture injury
	Vertical wing walls (Figure 10. 3)	Self-rescue not possible
	Steep or slippery surfaces and river-banks	Boaters unable to portage weir, assisted rescue difficult or impossible, slips, trips and falls
	Immersion in deep, cold water	Cold water shock, heart attack, hypothermia
	Movable gates, mechanical and electrical equipment	Entrapment, sudden increase in flow
Chemical (Section 10.3.4)	Contaminated sediment	Illness, death
Biological (Section 10.3.5)	Leptospirosis (Weil's disease)	Illness, death

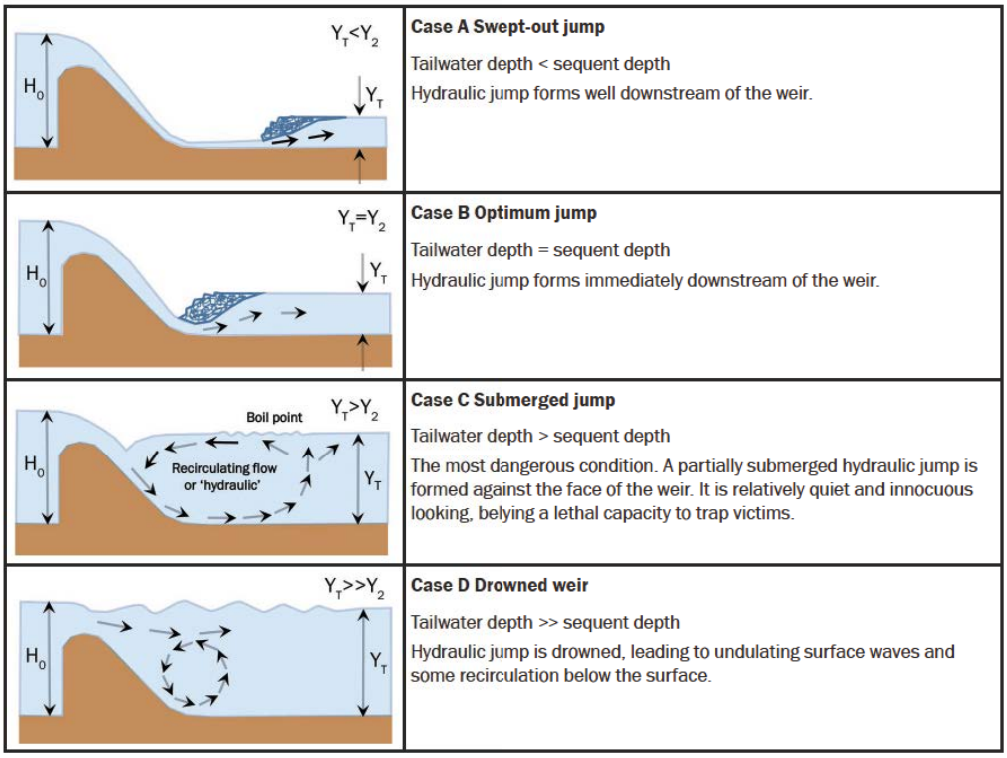


Figure 10.1 Weir flow types (from Tschantz and Wright, 2011)

The hydraulic hazard at a weir can vary with flow and tailwater conditions and a weir that is innocuous during low flows may become hazardous during high flow conditions (**Figure 10.2**). When tailwater level is low, the weir may develop a strong towback, and deep, fast flow conditions when the hydraulic jump is drowned by a high tailwater level. This change in hazard can be imperceptible, particularly upstream of movable gates where the water level remains constant, but the flow varies.

Weirs with a steep or vertical downstream face and a uniform hydraulic jump with no weak points are particularly hazardous due to the difficulty of escaping, as are curved weirs (**Figure 10.3**). See also **Appendix A1.1.6**.

Another type of hydraulic hazard is breach leading to the sudden release of a large quantity of water and flooding downstream. Breach (or dam-break) analysis can determine the risk to people, which is related to the speed of inundation, depth and velocity of floodwater, debris load and the nature of the area at risk (Defra, 2008). Sudden operation of movable weirs can lead to similar, if less dramatic, conditions.

Note

The hydraulic hazard at this vertical drop weir is low during low-flow conditions, but during high flows it develops a strong re-circulating flow along the entire length.

Figure 10.2 Change in hydraulic hazard between low and high flow conditions

The only signs of this hazardous weir from the watercourse upstream are the vertical wingwalls and the horizon line, indicating a sudden drop in water level.

Self-rescue is difficult at this weir due to the uniform hydraulic jump and vertical wing walls. A bank-based rescue would be difficult due to the high walls.

Pulteney Weir, Bath is visually pleasing, but in high-flow conditions the vertical steps create a hazardous re-circulating flow, which has claimed several lives. Rescue is difficult due to the curved plan form.

Figure 10.3 Hazards at weirs

10.2.3 Physical hazards

Underwater hazards can cause injuries to people and animals, foot entrapment or puncture/damage boats. These can lead to drowning when water pressure pushes the victim's body downstream and they are unable to hold their head above water. Hazards include gabion baskets, uneven materials, structures in poor condition or undermined by scour, boulders, and cracks in bedrock. These are not always visible to the observer, although uneven flow over the crest or apron may indicate damage such as missing blocks or local scour.

Weirs with vertical wing walls at either side are particularly hazardous due to the difficulty of either self or assisted rescue. Steep or slippery river-banks or surfaces next to the weir can cause visitors to slip and fall into the river, or make access or egress difficult for water users and rescuers. This may also mean that boaters have no choice but to attempt to shoot the weir.

UK waters are classed as cold (10°C to 15°C) and a deep, cold weir pool downstream of a weir can present additional hazards. Cold water shock is the short-term involuntary response to sudden immersion in cold water, leading to hyperventilation and potentially heart attack, even in young and healthy people. Although this response subsides in time, there is a residual risk of hypothermia.

The operation of movable gates (particularly hand winding) can pose a risk to weir operators. The operation of gates can cause flows or water levels to change without warning, presenting a risk to anyone who is on or in the water nearby. Historic paddle and rymer weirs involve lifting boards against water pressure and present a manual handling risk.

10.2.4 Chemical hazards

Contaminants in accumulated sediments upstream of weirs can cause burns, illness or death. The risk of mobilisation during works in or around weirs increases the potential for short-term sediment disturbance, or direct exposure of contaminants to site operatives or members of the public. In addition, removal or alteration of a weir structure can alter the longer term movement and deposition of contaminated sediment downstream of the original source.

Where contaminated materials (chemical or biological) are known or suspected to be present, risk and Control of Substances Hazardous to Health (COSHH) assessments should be carried out before works start. Controls may need to be put in place before works can begin, and assessments should be reviewed and amended as they progress. Typical aspects to consider include protection of site staff and construction operatives, restricting access by members of the public and livestock, and potential impacts upon the surrounding environment (eg surface water, groundwater, nearby properties and rights-of-way).

10.2.5 Biological hazards

Biological hazards include waterborne diseases such as Leptospirosis (Weil's disease), which is caused by a bacterium transmitted through rats or cattle urine. Although not unique to weirs, warm bodies of retained water can provide an ideal environment for harbouring and transmitting the disease in the summer months. Humans may be infected when open cuts or mucus membranes come into contact with urine or contaminated water.

10.2.6 Weir assessment system

In the UK, a weir assessment system for hydraulic hazards helps determine whether urgent action is required to reduce risk. A summary is given in **Table 10.2** and full details are in Environment Agency and Rescue 3 (UK) (2009). The nature of the river downstream (**Table 10.2**) is described in accordance with the international river grading system (**Table10.3**).

Table 10.2 Summary of weir assessment system (after Environment Agency and Rescue 3 (UK), 2009)

Nr	Description	Low risk	High risk
Step 1: Assess hydraulic hazard for range of flow and tailwater conditions			
1	Towback distance	None	>5 m
2	Depth of hydraulic jump	None	>1 m
3	Height of drop over weir	None	>2.5 m
4	Slope of weir face (from vertical)	None	<30°
5	Floating debris in hydraulic jump	None	>25% of length of jump
6	Uniformity of hydraulic jump	Broken feature	Uniform
7	Sides of the hydraulic jump	Both open	Both closed
8	Orientation of hydraulic jump to approach flow	<30°	90°
9	Additional hazards in or downstream of the weir	None	In main flow
10	River bed composition at base	Drowned or non-modular	Rock, debris
Step 2: Assess the likelihood of harm based on access to the weir from land or water, control measures to prevent access and ability to self-rescue			
11	Public access from land or water	None	Access
12	Control measures to prevent people entering the weir (see **Section 10.3.3**)	Adequate	Inadequate
13	Ability to self-rescue (see **Section 10.3.4**)	Possible	Not possible
Step 3: Assess weir risk rating based on hazard and likelihood and priority for mitigation measures			
Step 4: Assess weir rescue difficulty and determine the need for action			
14	Distance across the weir	<10 m	>75 m
15	Access to both banks	Easy	None
16	Shape of the weir	Straight	Curved
17	Towback length	None	>5 m
18	Remoteness	Urban	Remote
19	Nature of river downstream (see **Table 10.3**)	Up to Class I	>Class III or downstream weirs
20	Working area on banks	Good	None
21	Anchors for rope system	Good	Limited
22	Available rescue technique (see **Section 10.3.4**)	Full range	Helicopter only
23	Height of bank above base of hydraulic jump/stopper	<1 m	>3 m

Table 10.3 International river grading system

Class	Description	Example
I	Fast moving water with riffles, small waves and few obstructions. Risk to swimmers is slight, self-rescue is easy.	
II	Straightforward rapids with wide, clear channels. Swimmers seldom injured and group assistance seldom needed.	
III	Rapids with moderate, irregular waves. Swimmers rarely injured, self-rescue usually easy, group assistance may be required to avoid long swims.	
IV	Intense, powerful but predictable rapids. Moderate to high risk of injury to swimmers, self-rescue difficult, group assistance for rescue often essential, but requires practiced skills.	
V	Long, obstructed, or very violent rapids. Swims are dangerous and rescue often difficult even for experts.	
VI	Rarely attempted. Consequences of error are severe and rescue may be impossible.	

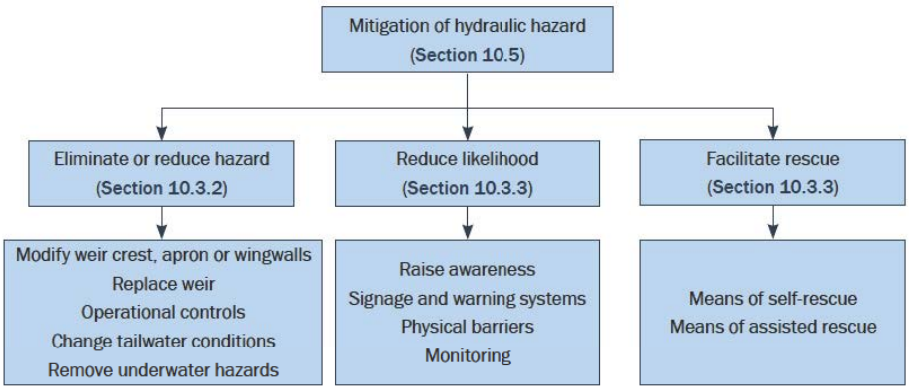


Figure 10.4 Mitigation measures

10.3 MITIGATION MEASURES

10.3.1 Overview

Mitigation measures fall into three broad categories as illustrated in **Figure 10.4**.

The choice of measures depends on factors such as conditions at the waterside, the presence of hidden hazards, and access to the weir from all directions (land on either bank or from the water up or downstream) and by whom (operations staff, member of the public and/or unaccompanied children). The likelihood of involuntary entry into the water due to crowd pressure should also be considered.

In the UK, water safety principles emphasise the importance of striking a balance between visitor self-reliance and management intervention (**Table 10.4**).

Table 10.4 Water safety principles (after National Water Safety Forum, 2014)

Principle	Detailed principles
Fundamental	No activity can be made completely risk-free. Risks imposed on non-participants and over which they have little or no awareness or control, can only be accepted if they are very low. Consider all benefits, dis-benefits and costs of water-related activities when judging whether risks are acceptable or further risk control measures are necessary. Learn from the past and look ahead by assessing the risks that can be foreseen. Avoid restrictions on access.
Responsibility	It is important to strike a balance between the self-reliance of the individual participant and management interventions. Everyone involved in a water-related activity has some responsibility for ensuring their own safety. Statutory bodies and responsible organisations may have only limited powers to require or enforce. Avoid risk controls that discourage people from organising or managing an activity, as far as possible. Children's risk perception skills will not be fully developed.
Partnership	People taking part in similar activities will accept different levels of risk. Risk control measures for one participant group may create risks to others. Work with visitor groups to promote understanding and resolve conflict. Collect incident data in partnership with others where possible.
Awareness	Ensure that people are aware of and understand potential hazards and risks. Inform and educate people about the nature and extent of hazards, risk controls in place and precautions they should take. Integrate safety information with other information provided to the public wherever possible.
Competence	Some people overestimate their skills and abilities to a certain degree, especially if impaired by alcohol or drugs. People have a range of abilities to recognise any given hazard. Some will overestimate, while others will underestimate and even fail to recognise a hazard exists. Where competence levels are deemed inadequate, training can improve competence.
Communication	Communicate the results of risk assessments and risk awareness material to participants, taking account of the language, literacy and cultural needs of the target audience.

10.3.2 Eliminate or reduce hazard

Measures to eliminate or reduce the hazard are passive and protect all user groups, including members of the public who do not always appreciate the risk associated with weirs and may be put at risk. These measures are desirable due to the emerging demand of the public to access rivers and weirs, and the associated issues, particularly in urban areas. Measures to reduce hazard are given in **Table 10.5 and Figure 10.5**. See also **Case study A3.10**.

Canoeists prefer to shoot a weir if it is safe to do so, as it is easier than portaging, and recommended safety features for weirs used by canoeists are given in **Box 10.1**.

Box 10.1 Safety features for weirs used by canoeists

Canoeists can shoot a weir at speed and may be able to overshoot (or 'boof') the towback, but this is risky and not advisable if the length of the towback exceeds half the length of the canoe (typically three to four metres).

Provide egress and access points above and below the weir, with a signed portage path parallel to the river, to allow canoeists and swimmers to exit the river above the weir, walk round the weir safely and re-join the river below.

Provide warning signs upstream of the portage so that canoeists can find the correct course to reach the portage safely.

Provide sufficient water depth over at least a portion of the crest to allow canoeists to negotiate the weir without grounding.

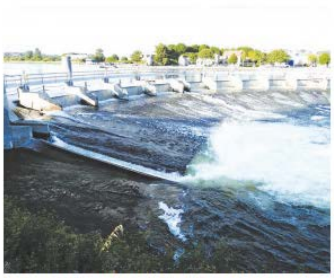
Provide an open-ended hydraulic jump that allows escape from either end, and a well-defined jet of water downstream of the weir to allow canoeists to escape the re-circulating hydraulic jump.

Provide sloping banks rather than vertical walls, which allow waves to break on them and dissipate energy.

Avoid bringing canoeists into contact with high or gradually accelerating flow velocities at abstraction or hydropower inlets or sluices, for example, by protecting the entrance of closed-ended inlet channels leading to sluices. Beware that a gently accelerating flow may pull canoeists or swimmers towards a hazard long before the hazard is visible. A velocity exceeding one metre per second is difficult to swim against and over 1.5 metres per second is impossible to paddle against.

Table 10.5 Measures to eliminate or reduce hazard

Measure	Description
Remove or replace weir	Remove weir and restore river. Replace with movable crest (eg hydraulically operated gates, inflatable dam or bascule gate with inflatable rubber bladder) (Schweiger, 2011).
Modify weir crest	Provide a chute for boaters to bypass a dangerous hydraulic jump. Remove a portion of the weir crest to create an irregular hydraulic jump (see **Case study A3.10**). Increase structure height to promote formation of a safer hydraulic jump (the required height can become too large to be acceptable) (Leutheusser and Birk, 1991).
Modify weir apron	Alter the weir apron (eg change the slope or add battens to deflect flow). Provide cascade with continuous energy dissipation (eg a rock ramp, grout bags or concrete steps).
Modify wing walls	Avoid or remove vertical wing walls and abutments so that swimmers can escape more easily or to facilitate assisted rescue from the bank.
Operational controls	Incremental operation of movable gates.
Change tailwater conditions	Alter tailwater depth to drown or change location of hydraulic jump.
Remove underwater hazards	Avoid or remove hazards that could cause puncture injury or foot entrapment.



This weir has an irregular hydraulic jump with a strong downstream chute (indicated by highly aerated water in the foreground) which will flush canoeists through.

Hydraulic deflector plates were installed downstream of a radial gate to disrupt the uniformity of the downstream hydraulic jump. These were orientated with omitted sections of the stilling basin end sill to provide flushing points in the downstream hydraulic.

This timber chute installed on part of an otherwise impassable weir allows canoeists to shoot a weir on a river in Germany. This is a common approach in mainland Europe

Figure 10.5 Measures to eliminate or reduce hazard

10.3.3 Reduce likelihood of harm

Measures to reduce the likelihood of harm do not eliminate the hazard, but reduce the probability of someone entering the weir, either from land or water (**Table 10.6**).

A guide to selecting risk control measures for weirs with land- and water-based activity is given in **Tables 10.7 and 10.8**. Regardless of the approach taken, where asset owners have multiple weirs, risk control measures should be consistent between sites.

Table 10.6 Measures to reduce likelihood of harm

Measure	Description
Raise awareness (Box 10.2)	Water safety education for water users. Provide information to professionals and stakeholders.
Signage and warning systems (Box 10.3)	Warning signs on river-bank directed towards water users rather than land users, showing recommended egress points well in advance of the weir. Manual warning boards or traffic lights. Audible alerts (eg sirens) at movable gates. Visual alerts (eg strobe lighting) at movable gates.
Physical barriers (Tables 10.7 and 10.8)	Safety boom upstream of weir to prevent access from the water (requires debris management and may create hazard to boaters) (**Figure 10.7**). Overhead warning boom upstream of safety boom. Safe egress point and portage around a weir for boaters. Safe moorings for boaters. Partial or full exclusion fencing to prevent access to the weir from land.
Monitoring	Video monitoring (CCTV or webcam). Police liaison and waterfront patrols.

Table 10.7 Risk control measures for weirs – land-based activity (after Canal & River Trust, 2012c)

Conditions	Controls
Daily operational presence, no public access	A
Operational access required, open to public, minimal public use, no hidden hazards	A, B
Operational access required, open to public, minimal public use, hidden hazards present	A, B, C, D, E
No operational access required, open to public, occasional unaccompanied children, no crowd pressure	A, B, C, D, E
No operational access required, many visitors including unaccompanied children, possible crowd pressure	A, F

Key

A – no action
B – clearly defined edges or demarcation
C – means of assisted rescue
D – means of self-recovery
E – partial exclusion fencing
F – exclusion fencing

Table 10.8 Risk control measures for weirs – water-based activity (after Canal & River Trust, 2012c)

Conditions	Controls
Access to weir from navigation	A
Craft will ground before weir crest	A
Risk of craft trapping on crest or in turbulence below	B, C, D
Risk of craft overtopping crest	D

Key

A – no action
B – consider warning signage
C – cost-benefit analysis of options
D – install safety boom

Raise awareness

Awareness of the hazards due to weirs can be raised by providing information on the location of weirs, the hazard and the best portage route. In the UK, river guide websites provide this information (see **Websites**). There is also a need for public education, particularly where weirs are located near residential areas and used for informal recreation in the summer.

Websites

The UK Rivers Guidebook: **www.ukriversguidebook.co.uk**

British Canoeing Canoe Trail guides: **www.gocanoeing.org.uk**

Paddle Points: **www.paddlepoints.net**

The unintentional creation of new hazards should be avoided, and it is important to raise awareness with other weir owners and professionals. Hydraulic engineering textbooks tend to focus on the design of weirs for flow measurement, water level management or energy dissipation. There are very few that provide safety advice, so there is scope of greater coverage of safety issues.

Box 10.2 Reducing likelihood of harm by raising awareness

In Germany and Austria, 'Wassersport' 'Wanderkarten' or watersport maps provide navigation information on weirs, locks, white water grading and other features of interest, including large-scale diagrams of important weirs, clearly indicating the portages.

In Minnesota, USA, a public information leaflet describes the hazards due to weirs, what can happen and what to look for (Elverum and Smalley, 2003).

Signage and warning systems

Signage is the simplest approach and good practice guidance on signage is given in **Box 10.3**. If unauthorised or accidental swimming is a problem, 'No swimming' signs should be provided as a minimum, possibly with additional signs warning of hazards such as deep or shallow water, strong currents or underwater obstructions. More explicit signs such as 'danger of death' or a skull and crossbones warning will convey the message more clearly.

During implementation (whether removal, modification or construction), works at weirs should be signed for both land and water users to minimise the risk of boaters being put at risk by entering the works.

Where water levels are controlled by fixed crest weirs, an increase in flow results in both raised water level and velocity. On navigable rivers or waterways, the increased hazard can be indicated by water level against a gauge board and a passive warning system is sufficient.

Where movable weirs are used to control water levels, there may be an increase in flow velocity with little discernible change in water level. A boater may not be aware of the increased hazard and an active warning system controlled by operatives should be adopted. Manual warning boards, traffic lights, three phase warnings (green-amber-red) and gauge boards showing flow depth or air draught may be used. Trigger levels should be set to minimise the risk to the most vulnerable users such as hire boaters or new boaters. Warning signs should be located at a sufficient distance from the hazard to allow the boater to take evasive action, and must be visible to all craft. They should be accompanied by safe moorings where boaters can wait out a high flow event in safety. Further guidance can be obtained from the Canal & River Trust or from the Environment Agency on their navigable rivers.

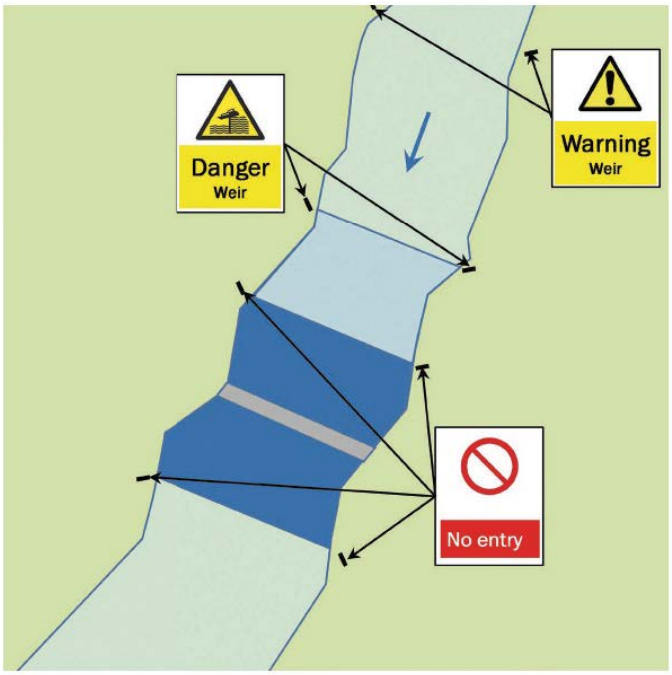
Hinged weirs (flap gates or sector gates) present little hazard when fully closed (vertical or near-vertical) or fully open (flat on the river bed). However, partially open, they create dangerous recirculating hydraulic jumps downstream that change as the gate moves and are impossible to navigate. It is important that water users are warned of their presence as they cannot be seen from upstream when looking downstream, and that emergency access to the weir on both sides and recreational access both over and around the weir on one side are provided.

Box 10.3 Warning, danger and restricted zones (from USACE, 2006)

In the USA, public access is prohibited immediately upstream and downstream of all weirs owned by the US Army Corps of Engineers and any other structures with similar hazards (USACE, 1996 and 2006). Three zones are defined upstream and downstream of a weir:

- **Zone 1 Warning area:** boaters are warned of impending dangerous conditions.
- **Zone 2 Danger area:** boaters are notified that the weir is a specific distance ahead and that they are in immediate and grave danger.
- **Zone 3 Restricted area:** signs are placed to prohibit access.

The extent of a restricted area is based on hydraulic criteria and operational considerations. This is so that a boater upstream can reach shore before being carried by currents into the weir, or to allow a reasonable expectation of rescue in the event of an accident, and to prevent a swimmer or boat without power downstream of the weir from being drawn into it. The restricted area should also encompass areas of turbulent waters caused by the operation of the works that create significant risk of swamping or capsizing a small boat. Restricted area boundaries are based on high flow conditions, and do not vary with fluctuating flows, intermittent discharges, or seasonal variations.



Physical barriers

Physical barriers have advantages and disadvantages, for example fencing to prevent entry to the watercourse can prevent self-recovery from the river.

Safety booms should be provided if there is a risk of boats accessing or overtopping the weir crest. Those designed to restrain loose powered craft can be a dangerous barrier to unpowered craft, particularly in strong stream or spate conditions. Booms also collect debris, which can be dangerous to the public and costly to remove.

Install a boom at an oblique angle across a river (**Figure 10.6a**). This will direct the debris to one bank from where it can be removed more readily, and allows swimmers and boaters caught up in the boom to move along the boom to the bank. The boom end pile or fixing point should be on or set into the bank to allow self-rescue by people from the environment to the bank, and the bank should be easy to access and egress.

Avoid installing a boom at right angles across a river as it will sag downstream, taking up a 'U' shape in plan. This will accumulate debris in the centre of the river, and canoeists and swimmers trapped at the middle of the 'U' will be unable to get out, swim or paddle back against the current (the same issue as shown in **Figure 10.10**).

A boom stirrup can be installed within a boom to allow the passage of canoeists or swimmers while retaining the integrity of the boom. These comprise a prefabricated flat metal 'U' in profile whose length and fixings are identical to a single barrel and can be inserted anywhere along a boom by removing or replacing a barrel. The stirrup can be located to guide canoeists to the best route over the weir, to a dedicated canoe chute or conjunctive fish pass. Signage is unnecessary as canoeists who are sufficiently expert to shoot the weir will find the route (**Figure 10.6c**).

Safety booms may sometimes be needed at weirs on rivers with no navigation authority, to guide swimmers away from or guard hazards.

Options for canoe portages are shown in **Figure 10.7**. Some general design principles are given here, while more detailed guidance is available from British Canoeing (see **Websites**):

- Locate an egress in slack water, installing boulders upstream to create an eddy if necessary.

a A safety boom upstream of a weir should be installed at an oblique angle to direct debris towards one bank where it can be removed.

b A canoe stirrup inserted into a barrel chain can allow canoeists to negotiate through a boom to shoot a weir, seen here in a swimming pool.

c A canoe stirrup should wide enough for large canoes.

d Even wildlife can use the canoe stirrup.

Figure 10.6 Good practice for safety booms

- Steps should be solid, not undercut, to avoid trapping the gunwale of a canoe.
- Flat surfaces should be no more than 0.3 m above the water for ease of disembarking and all edges should be rounded.
- Small mooring rings are useful, but avoid handrails that trap debris and can get in the way.
- If using concrete, the surface should be tamped parallel with the flow direction to encourage self-cleansing and reduce the need for silt removal.
- Provide appropriate signage visible to both water and land users. This is particularly important on navigations where mooring boats can block a portage, leaving no gap for canoeists to egress.

Conjunctive fish passes provide sufficient width and draught for canoeists to pass in the downstream direction, while allowing fish to migrate upstream. Some options are shown in **Figure 10.8** and some general design principles are given as follows. More detailed guidance is available from British Canoeing (see **Websites**).

- The canoe chute should be 1.5 m wide with clear space for paddles on either side and a minimum draught of 0.3 m at Q95.
- The plunge pool should be at least one metre deep and three metres long, to allow fish to rest and prevent canoes from making contact with the river bed or Larinier baffles.
- The approach flow should be slow-moving water to allow canoes to tilt to the slope of the pass without grounding and to allow fish to rest.
- The entry and exit should be free from obstructions.
- Larinier baffles should be rounded to minimise damage to fish and canoes.
- Upstream wingwalls should be sloping to minimise debris accumulation.
- All exposed edges should be rounded to minimise injury to persons, equipment and fish, and to minimise debris accumulation.

Websites
British Canoeing: **www.britishcanoeing.org.uk**

Monitoring

Monitoring, police liaison and waterfront patrols may be worth considering if there is a risk of conflict between unauthorised visitors and other users.

Beaches are ideal if gently sloping with a clear length of five metres and a slope of 1:10 or less.

Slipways are the man-made version of a beach and can be cut into a suitable bank. A slipway should extend at least one metre below the lowest known water level without encroaching on navigation, and should have a slope of 1:10 (or 1:15 for the less able).

Steps are useful for steeper banks and should extend below water level. They should be 1.5 m wide (no less than one metre) on the approach and five metres wide at the water's edge to allow a canoeist to pull alongside.

Jetties are ideal if the egress is sited adjacent to deep water, in dense reeds or if the river-bank is very steep. Here, platforms at different levels allow access and egress as water level varies.

Floating pontoons are useful if the water level varies greatly or no other options are suitable, but require maintenance. They should have a flat surface no more than 0.3 m above water level and be capable of supporting at least two paddlers and their craft without excessive tilting.

Figure 10.7 Options for canoe portages (courtesy Chris Hawkesworth)

Side by side passes can be used where flow is sufficient. The inlet invert level of the canoe chute invert should be slightly higher than that of the fish pass invert to maintain flow to the fish pass during low flow conditions.

Here, a Larinier fish pass (on the right) and canoe chute were installed in a former by-wash. The bridge was raised to give extra headroom.

Conjunctive canoe/fish passes must provide suitable velocities for fish.

This brush-furnishedfish pass uses reed-like bristles which allow fish to thread through or over them whilst avoiding damage to canoes brushing over the top.

Rock ramps are more natural and can be designed to provide a clear passage for canoes down the rock ramp while allowing upstream fish migration. Strategically placed rocks at the sides cater for slower fish.

Figure 10.8 Options for conjunctive fish passes

10.3.4 Facilitate rescue

Measures to facilitate self-rescue or assisted rescue should be a last resort as they require active intervention, may be unsuccessful, and rescue equipment could be at risk of vandalism. Rescue methods suitable for weirs, their applications and limitations are given in **Table 10.9** and measures to facilitate rescue are given in **Table 10.10**. Further information on rescue methods is available in Ferrero (2006).

Table 10.9 Rescue methods suitable for weirs

Method	Description	Applications and limitations
Self-rescue	Swimmer swims across hydraulic jump to a weak point, pushes off the bed to escape the tow back or drops to bed and escapes with flow near bed.	Hydraulic jumps with a weak point. Any weir width. Residual risk of entrapment in objects on river bed.
Reaching rescue	Rescuer presents long object such as a paddle or pole to victim as a rescue aid.	Weirs with bridge above. Narrow weirs (eg < 4 m wide) with access to river-bank near victim.
Throw line rescue	Rescuer throws line or rope from bank or bridge.	Weirs with bridge above. Wider weirs (eg < 40 m wide) with access to river-bank near victim. Range ≈ 20 m, depending on length of throw line and rescuer's ability.
Live bait rescue	Rescuer attached to line jumps into watercourse and grabs victim – both are then pulled to bank by a belay team.	Requires team of suitably equipped rescuers. Rescuer must be willing to swim the rapid downstream if necessary.
Rescue with a large object	Rescuer presents floating object such as a canoe or lifebuoy on a line into weir for victim to grab.	Wide weirs, boat-based rescue from river downstream of weir.
Boat rescue	Rescue boat tethered at both banks approaches victim from downstream.	Wide weirs, boat-based rescue from river downstream of weir. Requires boat access to river and tethering points. Unsuited to weirs with white water rapids or another weir downstream.
Helicopter	Rescuer lowered on a winch attaches harness to victim who is lifted to safety.	Any weir. Unsuited to weirs with overhead power lines or overhanging trees.

Table 10.10 Measures to facilitate rescue

Type	Description
Self-rescue	Break in the hydraulic jump, a deep weir pool and egress points on both river-banks. Good access to weir from both land and water (eg low banks that are clear of vegetation, a bridge over or adjacent to the weir). Self-rescue equipment (eg grab rails, ladders). Horizontal chains along a vertical wall to allow someone to work their way along a wall, with egress at the end (eg steps) (**Figure 10.7**).
Assisted rescue	Good access to weir from both land and water for emergency services. Rescue equipment (eg life buoys, throw lines), although this carries a risk of theft or vandalism. Harness attachment points or rope belay points (eg mature trees, stakes in ground) (see **Figure 10.10**). Rescue training.

Figure 10.9 Measures to facilitate rescue

Belay points for boatwork should be installed obliquely across a river so that a rescuer can reach the safety of the bank easily (**Figure 10.10**). Installing belay points at right angles can allow the rope to sag in the centre of the river, forcing the rescuer to work against the current to reach safety.

Note

The horizontal chains installed on piers immediately upstream of a weir will facilitate self-rescue, should someone be unfortunate enough to miss the portage.

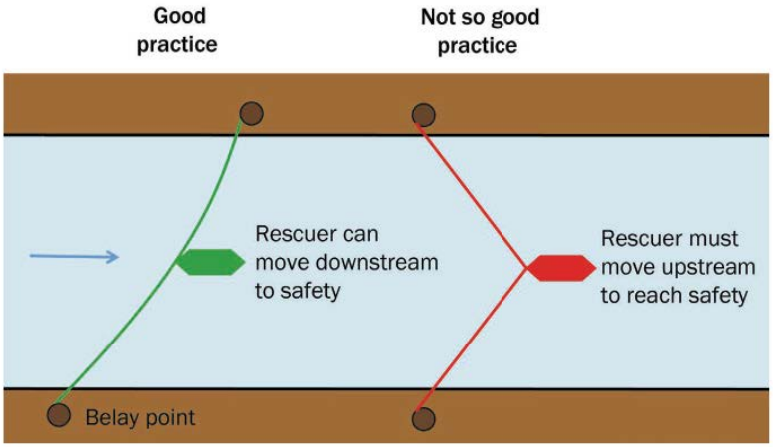


Figure 10.10 Belay points for boatwork

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Weir Assessment System

Cyfoeth Naturiol Cymru
Natural Resources Wales

Rescue3 EUROPE

NATURAL RESOURCES WALES / RESCUE 3 EUROPE WEIR ASSESSMENT SYSTEM

Name of assessor: _____

Date of assessment: _____

WEIR INFORMATION

Name of weir / site: _____

Other names weir known as: _____

Weir location and river: _____

Grid reference: _____

RIVER FLOW INFORMATION

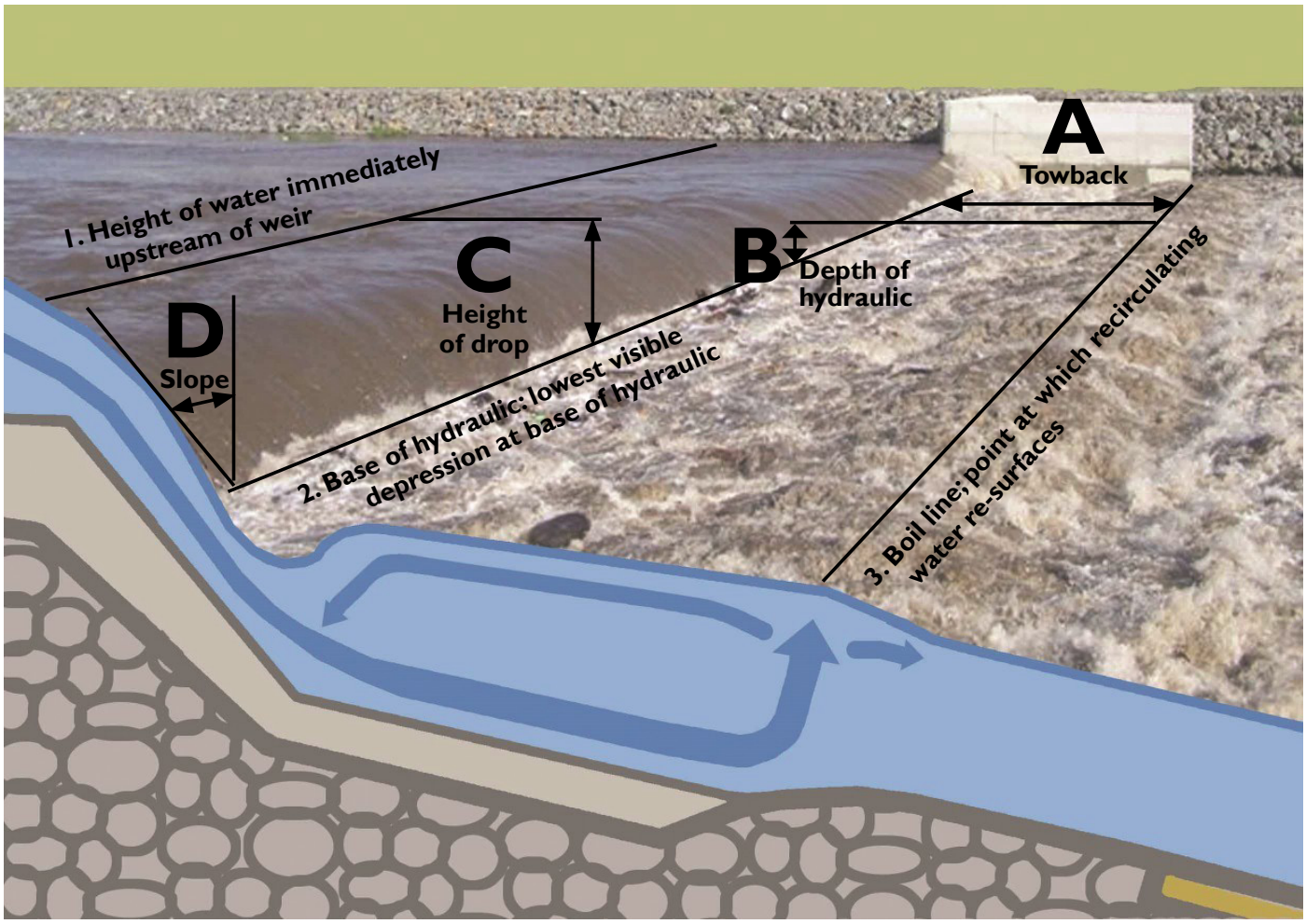
Reference Gauge Location: _____

	River level (m)	Flow range (m^3/s)
Low		
Medium		
High		
Flood stage		

River level on day of assessment - level (m) & flow (m^3/s)

_____ L / M / H / VH

WEIR FEATURES AND HAZARDS



FEATURES/HAZARDS

A. Towback:
The distance from the base of the hydraulic/stopper (2) to the boil line (3)

B. Depth of hydraulic/stopper:
Vertical distance from top of boil line (3) to base of hydraulic (2)

C. Height of drop:
Vertical distance between water level immediately upstream of weir (1) and base of hydraulic/stopper (2)

D. Slope:
Angle of water flowing over face from vertical

1. WEIR HAZARD

How to use this table:

For each hazard, select one description and circle the corresponding score. Add up the circled scores, write the total in the Weir Hazard Score box and assign the corresponding Weir Hazard Level.

	SCORE
A. TOWBACK	
No visible towback	0
< 1m	1
1 - 2m	2
2 - 3m	3
3 - 4m	4
> 4m	5
B. DEPTH OF HYDRAULIC/STOPPER	
No visible hydraulic/stopper	0
< 0.3m	1
0.3 - 1m	2
> 1m	3
C. HEIGHT OF DROP OVER WEIR	
No visible drop	0
< 0.3m	1
0.3 - 1m	2
1 - 2.5m	3
> 2.5m	4
D. SLOPE OF WEIR FACE (see fig 1)	
Structure drowned out - no weir face present	0
> 60°	1
45° - 60°	2
30° - 45°	3
< 30°	4
E. FLOATING DEBRIS IN HYDRAULIC/STOPPER	
No floating debris	0
Up to 10% of hole contains debris	2
10 - 25% of hole contains debris	3
> 25% of hole contains debris	4
F. UNIFORMITY OF HYDRAULIC/STOPPER	
No visible hydraulic/stopper	0
Broken feature with multiple flush points or 1 main flush point	1
One or two small flush points in the hydraulic/stopper	2
Totally uniform with no breaks and flush points	5
G. SIDES OF HYDRAULIC/STOPPER	
Both open	0
One side open/one side closed	2
Both closed	4
H. ORIENTATION OF HYDRAULIC/STOPPER TO FLOW (see fig 2)	
No hydraulic/stopper present	0
< 30° to current	1
> 30 but < 90° to current	2
90° to current	3
I. ADDITIONAL HAZARDS IN OR DOWNSTREAM OF WEIR eg strainers, weirs or significant rapids	
No additional hazards	0
Hazard present but not in main flow	1
Hazard present in main flow	5
J. COMPOSITION OF RIVER BED AT THE BASE OF WEIR	
Structure drowned out/non-modular	0
Concrete	1
Sand or gravel	2
Rock or debris	3

Figure 1: Slope of weir face

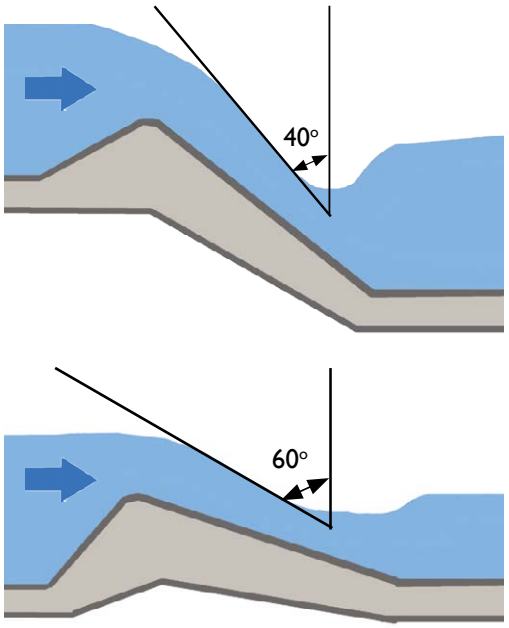
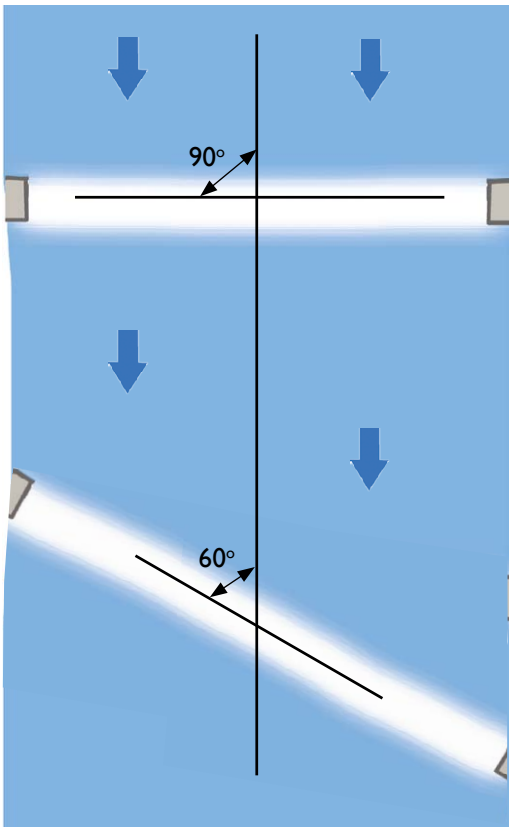


Figure 2: Orientation of hydraulic/stopper to flow



WEIR HAZARD SCORE:
Sum of scores selected for each hazard

WEIR HAZARD LEVEL:
Corresponding Hazard Level from table below

Weir Hazard Level:

Hazard Score	>0-10	11-15	16-20	21-30	31-40
Hazard Level	V Low (1)	Low (2)	Med (3)	High (4)	V High (5)

2. LIKELIHOOD OF WEIR TO CAUSE HARM

How to use this table:
For each consideration, select one description and circle the corresponding score. Add up the circled scores and write the total in the Likelihood of Weir to Cause Harm box.

SCORE

PUBLIC ACCESS

Public access from land and water – is the structure in a publicly accessed location?

Land upstream river right	no public access from land/bank	0
	public access from land/bank	0.25
Land upstream river left	no public access from land/bank	0
	public access from land/bank	0.25
Land downstream river right	no public access from land/bank	0
	public access from land/bank	0.25
Land downstream river left	no public access from land/bank	0
	public access from land/bank	0.25
Water upstream	no access to weir from upstream	0
	access to weir from upstream	0.5
Water downstream	no access to weir from downstream	0
	access to weir from downstream	0.5

CONTROL MEASURES

Are there control measures in place, eg fences or booms, to prevent people from entering the weir?

Land:

Upstream river left	adequate control measures in place	0
	inadequate control measures in place	0.25
Upstream river right	adequate control measures in place	0
	inadequate control measures in place	0.25
Downstream river left	adequate control measures in place	0
	inadequate control measures in place	0.25
Downstream river right	adequate control measures in place	0
	inadequate control measures in place	0.25

Water:

Upstream	Structure not in main channel/boom present	0
	Structure in main channel/no boom present	0.5
Downstream	Controlled by boom or by high speed of water	0
	No downstream control measures	0.5

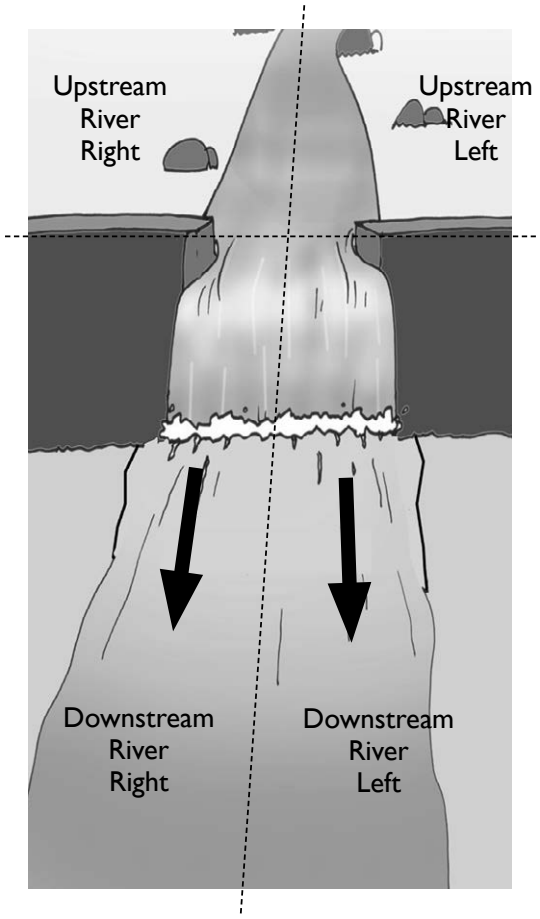
ABILITY TO SELF-RESCUE

Taking into account the existing control measures, if a person were to fall into the water above/beyond/outside the existing control measures can they self rescue before entering the weir?

Upstream river left	can self-rescue	0
	can't self rescue	0.25
Upstream river right	can self-rescue	0
	can't self rescue	0.25
Downstream river left	can self-rescue	0
	can't self rescue	0.25
Downstream river right	can self-rescue	0
	can't self rescue	0.25

SECTIONS OF A RIVER

The river/waterway can be divided into four sections for ease of identification: upstream and downstream of the weir/hazard and river left and river right. This is always done from the perspective of looking downstream.



LIKELIHOOD OF WEIR TO CAUSE HARM
Sum of scores selected for each consideration

LIKELIHOOD OF WEIR TO CAUSE HARM LEVEL: ( )
Corresponding Likelihood Level from table below

Likelihood Level:

Likelihood Score	0-1	>1-2	>2-3	>3-4	>4-5
Likelihood Level	V Unlikely (1)	Unlikely (2)	Likely (3)	V Likely (4)	Almost certain (5)

3. WEIR RISK RATING

Risk = Hazard x Likelihood

The Hazard and the Likelihood have been calculated in the previous tables.

Using these results, the Weir Risk Rating Score can be calculated:

WEIR HAZARD LEVEL:
Level of 1-5 taken from Table 1 (page 3)

LIKELIHOOD OF WEIR TO CAUSE HARM LEVEL:
Level of 1-5 taken from Table 2 (opposite)

WEIR RISK RATING SCORE:
Multiply Hazard Level by Likelihood Level (from above)

WEIR RISK RATING LEVEL:
Corresponding description from table below i.e. Low

Hazard / Likelihood	1 Very Low	2 Low	3 Medium	4 High	5 Very High
1 Very Unlikely	1	2	3	4	5
2 Unlikely	2	4	6	8	10
3 Likely	3	6	9	12	15
4 Very Likely	4	8	12	16	20
5 Almost Certain	5	10	15	20	25

Score	Risk Level	Action
1 - 5	LOW	Action required to reduce the risk, although low priority. Time, effort and cost should be proportional to the risk.
6 - 10	MEDIUM	Action required soon to control. Interim measures may be necessary in the short term.
12 - 25	HIGH	Action required urgently to control the risks. Further resources may be needed.

4. WEIR RESCUE

How to use this table:
For each rescue consideration, select one description and circle the corresponding score.
Add up the circled scores and write the total in the Weir Rescue Difficulty box.

A. DISTANCE ACROSS WEIR/RIVER	SCORE
< 10m	1
10 - 20m	2
21 - 50m	3
51 - 75m	4
> 75m	5
B. ACCESS TO BOTH BANKS	
Easy access to both banks for people & vehicles	0
Easy access to both banks for people only	1
Easy access to only 1 bank for vehicles & people	2
Easy access to only one bank for people	3
Difficult / restricted access to both banks for people & vehicles	4
No access to either bank	5
C. SHAPE OF WEIR	
Straight	1
Curved/multi-directional/compound structure	3
D. TOWBACK	
No visible towback	0
< 1m	1
1 - 2m	2
2 - 3m	3
3 - 4m	4
> 4m	5
E. REMOTENESS	
Urban	1
Rural/semi-urban	2
Remote	4
F. NATURE OF RIVER DOWNSTREAM OF WEIR (see opposite)	
Up to Class I	1
Class II	2
Class III	3
> Class III	4
Additional downstream weirs	5
G. WORKING AREA ON BANKS	
Good working areas on both banks	1
Good working areas on one bank only	2
Limited or restricted working areas on both banks	3
No working areas on either bank	4
H. ANCHORS FOR ROPE SYSTEM	
Good anchor points on both banks	1
Good anchor points on one bank only	2
Limited anchor points on both banks	3
I. AVAILABLE RESCUE TECHNIQUES	
Full range of single and twin bank methods with easy ability to cross channel with ropes, eg bridge, short throw or shallow crossing	0
Full range of single and twin bank methods but difficult to cross channel with ropes, eg bridge, short throw or shallow crossing	1
Limited to single bank methods or use of paddle boat	2
Limited to single bank methods or use of motorised boat	3
No bank-based options available	4
Helicopter only	5
Helicopter not possible (overhead wires etc)	6
J. HEIGHT OF BANKS ABOVE BASE OF HYDRAULIC/STOPPER	
< 1m	1
1 - 3m	2
> 3m	3

WEIR RESCUE DIFFICULTY SCORE:
Sum of scores selected for each rescue

WEIR RESCUE DIFFICULTY LEVEL: ( )
Corresponding Difficulty Level from table below

Weir Rescue Difficulty Level:

Difficulty Score	*< 20*	*20-25*	*> 25*
Difficulty Level	*Low (1)*	*Medium (2)*	*High (3)*

International River Grading System

Class I
Clear section of moving water or simple rapid which may contain low waves and few or no obstructions. Clear route through section of river.

Class II
Medium rapid which may contain irregular waves, small stoppers and simple obstructions. Clear route through section of river.

Class III
Larger rapid which may contain medium, irregular waves, medium stoppers and multiple obstructions. Recognisable route between obstructions/features.

> Class III
Heavy rapid which may contain high, irregular waves, large stoppers and numerous obstructions. No easily recognisable route between obstructions/features.

NOTES

NOTES

NATURAL RESOURCES WALES / RESCUE 3 EUROPE WEIR ASSESSMENT SYSTEM

RESULTS

Complete the tables within this workbook and transfer the results to this page

	Score *(from completed tables)*	**Level** *(from completed tables)*
Weir Hazard *(Table 1, page 3)*		( )
Likelihood of Weir to Cause Harm *(Table 2, page 4)*		( )
Weir Risk Rating *(Table 3, page 5)*		( )
Weir Rescue Difficulty *(Table 4, page 6)*		( )

Cyfoeth Naturiol Cymru
Natural Resources Wales

Rescue3 EUROPE

Rescue 3 Europe
The Malthouse
Llangollen, Denbighshire
LL20 8HS
Tel: 01978 869069
Web: www.rescue3europe.com
Email: info@rescue3europe.com

Annex C

British Canoeing Information Sheet – Stand up Paddleboard Safety, *Choosing the right leash* – November 2020

INFORMATION SHEET

Contact: safety@britishcanoeing.org.uk

Subject	**Stand Up Paddleboard (SUP) Safety Choosing the right leash**
Date Issued	**November 2020**

The leash is a key source of safety when Paddle boarding. It keeps you and your paddleboard together when things don't go to plan.

However:
To stay safe it is essential to choose the right kind of leash for the environment and conditions you are paddling in.

Failure to do so could put your safety at risk.

If you end up in the water wearing the wrong leash on moving water i.e. flowing rivers, tidal rivers or in tidal races, this can cause the leash to become snagged or caught on obstacles and to become entangled. This presents a danger that is difficult to extract yourself from. In these conditions a quick release waist leash is the best option and could be essential if you are in danger.

The following appraises and gives advice on which leashes suit different environment.

1. Ankle and Calf (knee) leashes
Suitable environments for use:
Lakes, canals, sea / coastal bays, surf and slow moving deepwater rivers

a. Ankle Cuff leashes
These are the most common leash, they often comes with your board if you buy a package. They are easy to wear and to fit. Always attach them to the same leg each time you paddle, that way you will always know where to release them if needed.

b. Calf Cuff (knee) leashes
These are similar to an ankle leash but the cuff attachment is slightly larger and fits just below your knee. Some people may prefer this type of leash for ease of attachment but the environments in which they should be used are similar.

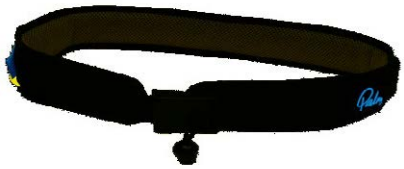
A curly leash is normally preferred for General SUP use

A Straight leash is mainly used for surfing

2. Quick release waist belt.
Suitable environments for use:
Moving/flowing water including, rivers, tidal rivers and estuaries, tidal races, white water rivers.

A waist leash is connected to a waist belt with a quick release buckle or fastening. It can be easily reached if you come off your board and are caught or held by the force of the water. When fitted and used correctly it releases you from your board and leash attachments freeing you from any dangerous entanglement.

It is normally worn around your waist and below the level of your buoyancy aid or pfd.
It can also be worn on top of your buoyancy aid if fitted high on the chest.



It is common practise to attach the cuff from a curly leash, which would normally attach to your ankle or calf, to the waist belt.

The following video uses a white water setting to demonstrate the potential problems that an ankle and calf leash can cause in flowing water and the advantage of a quick release waist leash in freeing the paddler. **Click here to view**

Case study
The need for a quick release waist leash has been illustrated on the tidal section of the river Thames below Teddington. Tidal rivers can be deceptive with slack water around high and low tide being followed by very fast flowing water on the incoming and outgoing tides.

On this section of the Thames it has led to paddlers colliding with fixed obstacles such as, pontoons, moored boats and buoys where the paddler and paddleboard have been swept either side of the obstacle and have been unable to free themselves. Through this experience the Port of London Authority (PLA), who manage the Thames Tideway; now require all SUP paddlers to use quick release waist belts rather than ankle leashes. The PLA have published safety guidance for SUP paddlers click **here** to view.

Safety check list for SUP paddlers
As well as choosing the right leash, remember to prepare properly for any trip on the water. British Canoeing have produced some tips on how to enjoy your paddling and staying safe, click **here** to view.