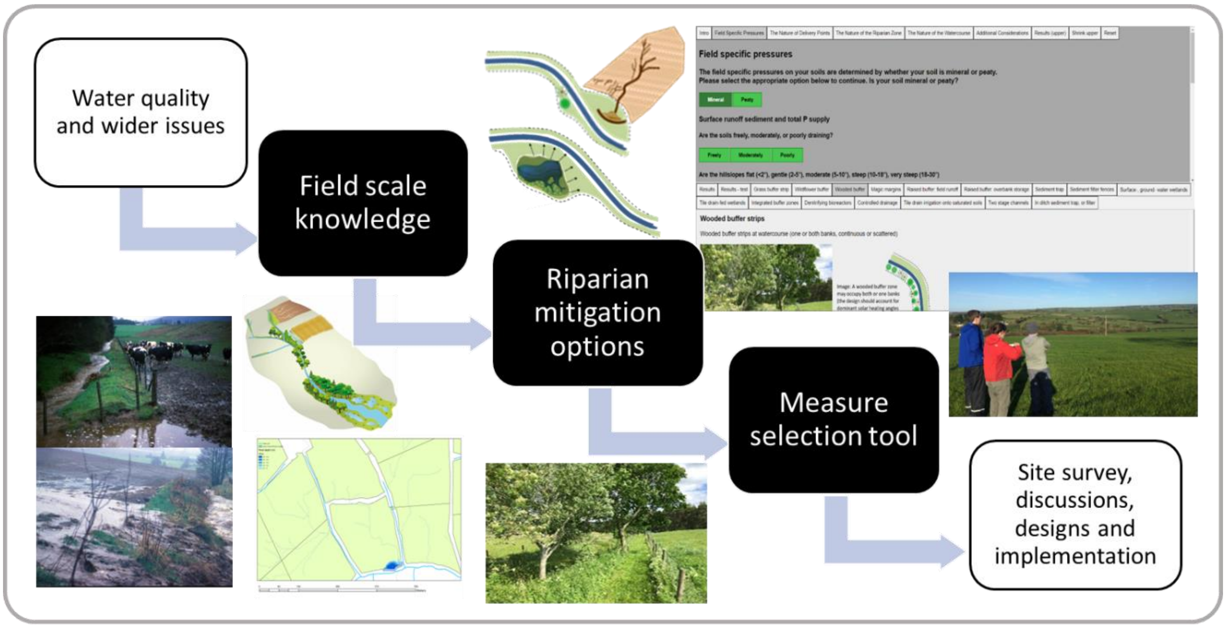
A handbook for the riparian mitigation measures selection tool



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Glossary of terms:

Buffer zone Managed zone between agriculture or development and a sensitive pollution receptor (for example, a stream)

Critical Source Area A zone of a field or landscape where a large pollution source and active transport pathways coincide

Converging flow When surface runoff is channelled (by local topography) into higher energy, erosive flows

Diffuse flow When surface runoff is spread across the slope, with less focussed energy and erosive power

Drainage ditch An open, surface drainage ditch dug as part of land drainage, usually straight in form

Floodplain The bottom valley alongside the stream or river side where flood water may leave the channel and flood deposits have contributed to the landform

Mineral soil A soil that is dominantly comprised of mineral material such as sands, silts and clays with only up to moderate organic matter content

Mitigation measures Measures placed in the landscape to mitigate pollution effects by controlling source areas or transport pathways

Peaty soil A soil that comprises mainly organic matter (peat) or has a surface horizon that comprises mainly organic matter

Pollutant effectiveness An assessment of the potential effects of a mitigation measure to achieve pollution retention in relation to its mode of action.

Riparian Land water interface affected by land and channel processes

Stream A natural channel that follows the landscape contours and is not man-made, but may be heavily modified in form (for example, deepened)

Subsurface drainage Artificial soil drainage including stone or tile drains or plastic pipe laid underground and often exiting at a watercourse

Tool In this context, a computer interface to a simple program implementing rules that aids the user in decision making through otherwise complex process steps

1. Rationale and remit

The riparian mitigation measures tool (hereby referred to as 'the tool') has the following aims:

- To use landscape context to prioritise between a long list of mitigation measures suitable for the riparian space.
- To give a consistent framework within which to apply rules to reject vs favour some measures based on user inputs to landscape questions.
- To introduce a wider set of riparian measures than may typically be considered and to educate on their modes of operation, and hence suitability, against landscape factors.
- Additionally, to raise awareness of how measures shown to be suitable against landscape constraints (field scale, as defined by user questions) may have varying potential effectiveness for different pollution reduction goals at catchment scales (defined by expert judgement outside of the tool process).

The tool functions by:

- Guiding a user (typically an advisor or catchment officer, often in a discussion with a practitioner) through a set of questions on the landscape, runoff and erosion pressures and pollution pathways to target edge of field mitigation measures.
- The user's answers then inform prioritisation or rejection from a set of sixteen measures for improving water quality.

The tool is not designed to take the place of professional and policy advice but to act as a screening and engagement tool leading to bespoke site survey for final decisions.

2. Development, reference to full methods and access to the tool

The tool was developed by the project group across The James Hutton Institute, Scotland, and Teagasc, Ireland, for the research project Specific Management and Robust Targeting of Riparian Buffer Zones (known as the Smarter BufferZ project; 2017-2022) funded by Irish EPA Research (Grant number 20017-W-LS-16).

A general description of the development of the tool can be found here and the full description in a science paper can be accessed through the tool website. Several development phases were involved including testing and refinement at each of the stages of: internal project group workshop (May 2022), project steering group meeting (Sep 2022) and at a stakeholder workshop for Irish advisory, policy, regulatory and catchment officers (Wexford, Nov 2022).

The tool and this accompanying handbook can be accessed via the webpage at:

https://measure-selection-tool.hutton.ac.uk/

3. The sixteen riparian mitigation options

The intention of the tool is to introduce and inform on the modes of operation of sixteen diverse riparian measures for pollution mitigation (Table 1). More commonly understood grass, wildflower and wooded buffers are considered according to suitability, alongside more novel, targeted measures for high erosion, or runoff situations and presence of artificial subsurface and open ditch drainage.

It should be noted that measures may often be best used in combinations depending on the circumstances. Examples of this are:

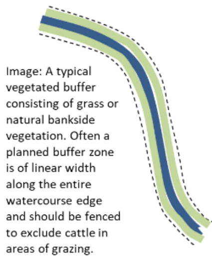
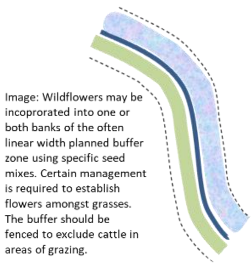
- When fields drains and surface runoff being both active pathways;
- When point measures for specific locations of convergent erosion pathways are located within a general grass or wooded margin space;
- When in-channel measures are used alongside measures at the watercourse margin.

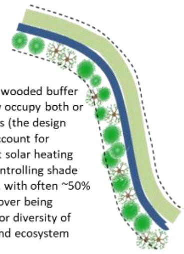
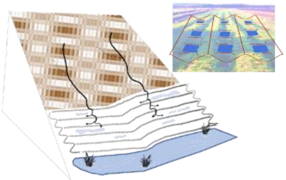
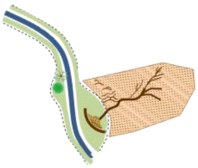
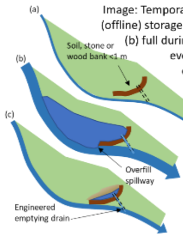
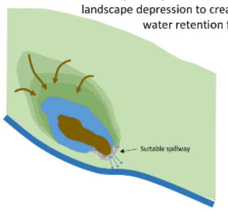
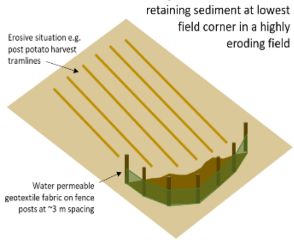
One measure, sediment filter fences, may be considered a ‘measure of last resort’ for example in temporary use alongside a highly erodible crop and has limited multiple benefits. However, many measures have considerable potential for enhancing multiple benefits that should be considered alongside pollution benefits in their planning. Examples of this are:

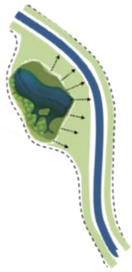
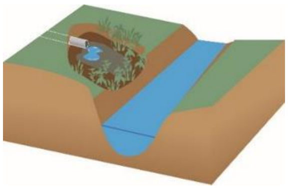
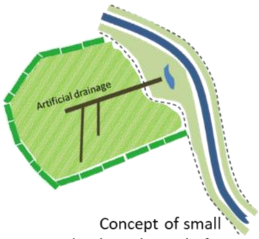
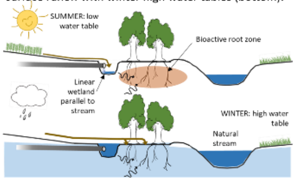
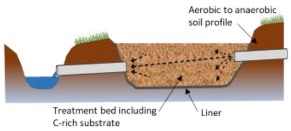
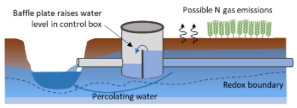
- Wildflower and wooded buffer zones having pollinator, stream shading and aesthetic values.
- Wetlands and other saturated buffer approaches that add diversity in soil conditions and maximise vegetation and habitat diversity whilst bringing benefits for soil carbon sequestration or retention.

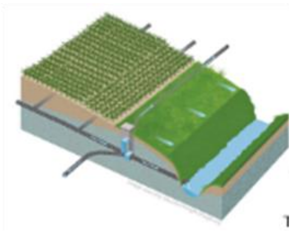
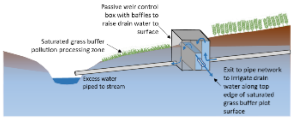
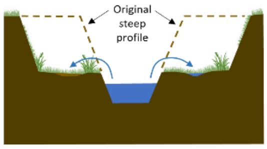
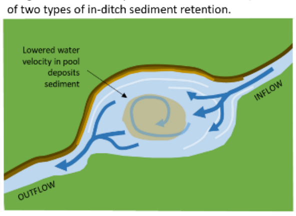
The measures were compiled by the Smarter BufferZ project team into a set of sixteen possible options after reviewing measures from around the world and the supporting evidence. As part of their development an exercise was undertaken by international experts to judge their potential effectiveness (ie upper ceiling of effectiveness for a well-designed, sited and maintained measure) for a range of pollutants and wider benefits. This is summarised in the tool outputs (see section 6) using a simplified scoring of low (L), medium (M) and high (H) (originally numerical scores of 1-2, 3 and 4-5, respectively in the database). The full database of the measures is given at: https://data.mendeley.com/datasets/ggc3pz78w4/1

Table 1. Summary of the sixteen mitigation measures forming the basis of the tool.

Measure group	Measure	Photo	Schematic of how it functions	Brief description and *key reference*
Baseline margin space	**Grass buffer strip**			Popular agri-environment scheme measure provides a physical barrier from agricultural activities, limited surface runoff trapping and bank stabilisation. Best if fenced for cattle exclusion. *Ref: Stutter et al. (2021)*
	Wildflower buffer			Enhancement on the grass filter strip using wildflower seed mixes for specific biodiversity, or even nutrient uptake or biomass goals. *Ref: Cole et al. (2020)*

	Wooded buffer		 Image: A wooded buffer zone may occupy both or one banks (the design should account for dominant solar heating angles controlling shade benefits), with often ~50% canopy cover being optimal for diversity of habitat and ecosystem services.	Inclusion of trees improves airborne pollution interception, deep rooting and nutrient uptake into biomass, habitat, hydromorphology and aquatic protection. *Ref: Stutter et al. (2019)*
Surface runoff and sediment options	**Magic margins**		 Image: Magic margin ridges perpendicular to slope (left) and showing the mini-dam concepts in the furrows (right)	A practical addition to grass buffers for soil erosion using a farm tied-ridger and potato drill plough to create min-dams (sown with wildflowers to stabilise) that encourage water and sediment retention. *Ref: not yet developed*.
	Raised buffer: field runoff		 Image: The concept of a raised buffer positioned at the base of a major pathway of muddy runoff, perhaps using a locally widened riparian space.	A bund (soil, stone or wood) can be placed across an overland flow pathway to interrupt the path, temporarily retain water and trap sediment. Spillways and exit pipes can be engineered to suit. *Ref: Wilkinson et al. (2013)*
	Raised buffer: overbank storage		 Image: Temporary filling of overbank (offline) storage (a) empty, pre-flood, (b) full during a flood (overbank) event, and (c) emptying of water after ~24-48 hours but having retained sediment after the event.	A bund (soil, stone or wood) placed onto floodplains temporarily stores overbank floodwater and traps sediment, engineered to drain back to the watercourse in <48 hours. *Ref: Nicholson et al. (2020)*
	Sediment trap		Image: Sediment trap, intercepting surface runoff pathways and enhancing existing landscape depression to create sufficient water retention for sediment settlement 	Enhancing of natural landscape depressions to trap water and sediment temporarily. Large surface areas benefit sedimentation. Outlets can be engineered. *Ref: Duffy et al (2016)*
	Sediment filter fences		Image: Sediment filter fence retaining sediment at lowest field corner in a highly eroding field 	Especially for high erosion risk from surface runoff on steeper slopes or after (often temporary in a rotation) high risk cropping. A geotextile barrier for sediment retention. *Ref: Vinten et al. (2014)*

Sub-surface pathway options	**Surface-, ground-water wetlands**			Permanently wet, vegetated wetlands enhancing natural ones or constructing new. Fed by upwelling groundwater and surface water. Requires adequate retention time for treatment. *Ref: Ockenden et al. (2014)*
	Tile drain-fed wetlands		 Concept of small wetlands at the end of a tile-drain in a widened riparian space.	Cutting back a main arterial field drain from exiting directly to water, instead directed into a small wetland zone (with permanent vegetation and higher C soils for treatment). *Ref: Carstensen et al. 2020.*
	Integrated buffer zones		Image: Integrated buffer zone functioning as a sediment trap and bioactive root zone in summer (top), compared to a particle deposition bed for surface runoff with winter high water tables (bottom). 	A zoned buffer approach comprising linear wetland and tree zone for interrupting pathways of surface erosion and field drains, with subsurface treatment amongst tree roots and particle deposition onto seasonally waterlogged soils. *Ref: Zak et al. (2019)*
	Denitrifying bioreactors		Image: Denitrifying bioreactor fed by tile drainage waters and using a C-media such as woodchip, mixed or graded with gravel to maintain hydraulic properties 	Engineered solutions for channelling high nitrate load pathways into a bioreactor fed with enriched organic C. Engineered in terms of flow rates, bed particle size and infiltration and C-dosing. *Ref: Carstensen et al. (2020)*
	Controlled drainage	 Image: Typical pre-made chamber used at the point of intervening on the drain.	Image: Drainage management structure used at end of subsurface soil drain to raise soil water level during autumn and winter to promote denitrification. 	Field tile drain discharges with high nitrate loads are seasonally shut off at a control valve so that the field slope becomes a saturated wedge to encourage natural denitrification. *Ref: Carstensen et al. (2020)*

	Tile drain irrigation onto saturated soils	Taken from www.transforming drainage.com 	Image: Drain water management structure using baffles to passively raise soil drain water to enable irrigation onto a saturated grass zone of carbon-rich topsoils 	Field tile drain discharges with high nitrate loads are raised to surface levels by a control structure to enable water distribution onto topsoils of suitable organic C content for natural denitrification. *Ref: Jaynes and Isenhart (2019)*
In-channel options	**Two stage channels**	 Image: Indiana watershed initiative	Image: Steep sided channel reprofiled to have widened, vegetated side 'benches' capable of temporarily holding flood water and retaining sediment as the second bed stage. 	Artificial, steep-sided, open drainage ditches are reprofiled to contain mini-floodplains that retain sediments during high flows, become vegetated and treat nutrients and stabilise banks. *Ref: Davis et al. (2015)*
	In ditch sediment trap, or filter	 An engineered wood chip in-stream filter trialled in UK. Photo credit: Newcastle University.	Image: Sedimentation pool in a stream channel; one of two types of in-ditch sediment retention. 	In-channel sediment traps comprising widened basins to inserted (contained) filter materials (e..g. woodchip). *Ref: Ockenden et al. (2014)*

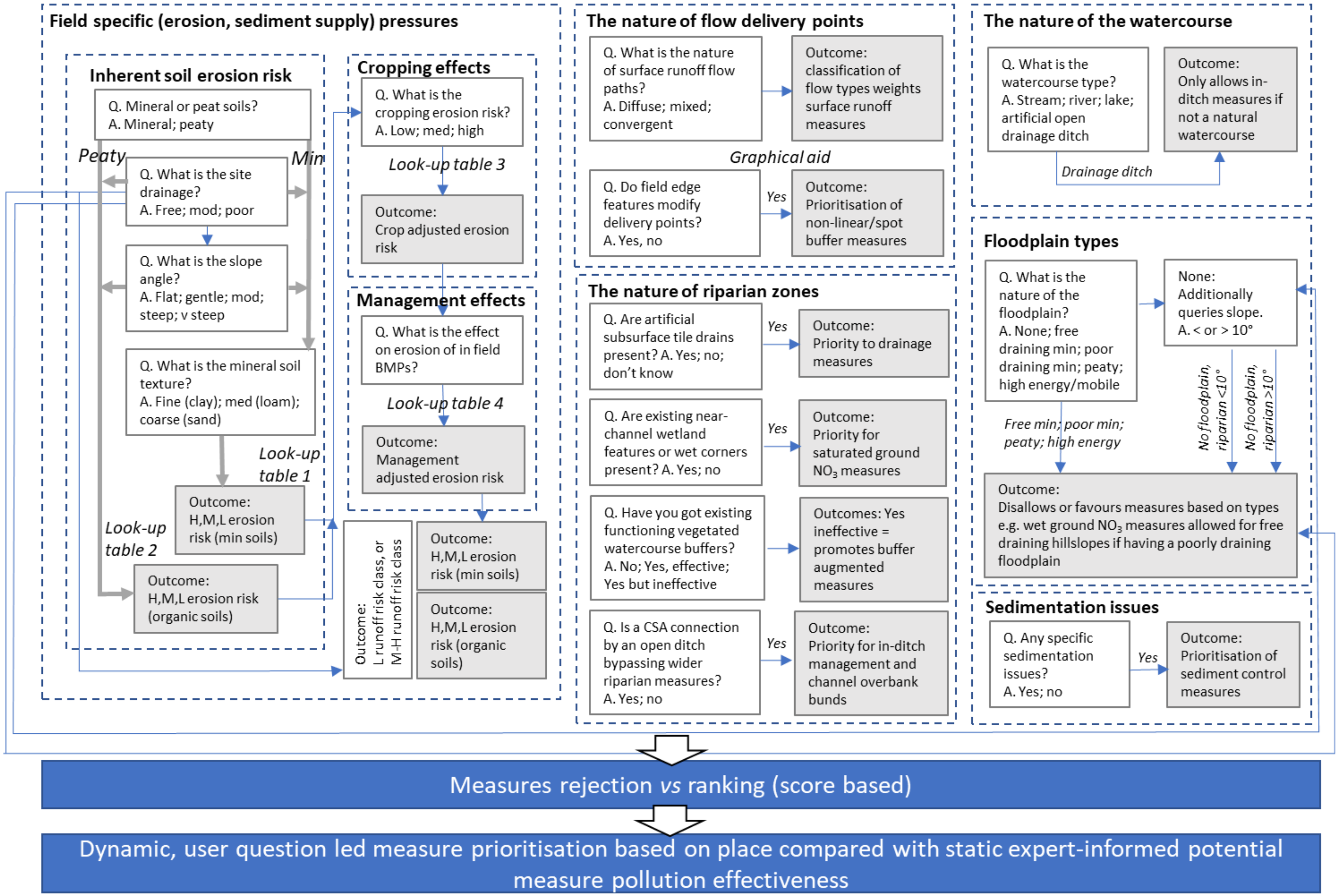
4. User question inputs for landscape context

4.1. Question overview

The question process was designed to use the minimum number of clear questions to address the relevant landscape factors that informed the place-specific attributes necessary to understand the functioning of different measures in that location. Key question aspects concerned the intensity of runoff and erosion pressures (affecting sediment and phosphorus transport), free draining landscapes for nitrate leaching, hillslope to floodplain slope profiles and soil water conditions and discerning dominant pathways between surface runoff and preferential pathways such as drains (that often bypass riparian surface mitigation methods) (see for example, Cloy et al., 2021).

The resulting fifteen questions were arranged in sections (each developed under tabs to be answered sequentially), namely: Field specific pressures; The nature of delivery paths, the nature of the riparian zone, the nature of the watercourse. Specific aspects within each of these measure input tabs are described in the report sections 4.2.1 to 4.2.4, below, with additional (habitat) considerations considered described in section 4.2.5.

Figure 1. Question structure, order and interactions in the final tool version.

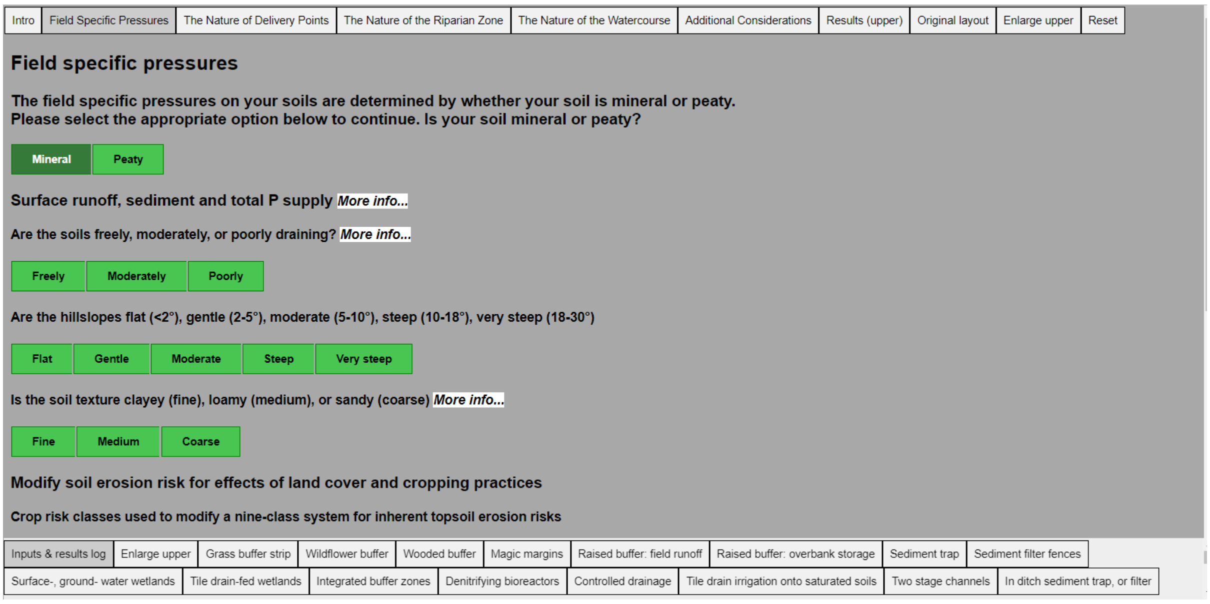


4.2. Question groups in the tool

General aspects of the question groups are discussed below as additional information alongside the guidance within the tool. Specific notes against individual questions are highlighted by a bulleted comment.

4.2.1. Field specific pressures

Figure 2. A section of the question input tab ***Field Specific Pressures***.



This section has a top line question '***Are the soils mineral or peaty?***', which subsequently sets out five, or four, questions for mineral or peaty soil master level options.

- ***Q. Are the soils mineral or peaty?*** – mineral should be selected if mineral material (proportion of sand, silts and clays) dominates the soil composition, for example long-time cultivated podzols, gleys and brown soils, including most grassland soils. Peaty soils should be selected if organic matter (>20% organic carbon or around 35% organic matter) dominates the soil, for example any peats, podzols or gleys with surface layers comprised mainly of organic matter, and this may include upland grazing and some lowland cultivation.

For mineral soils questions on texture and drainage are included. The variation for peaty soils is that drainage and texture questions are omitted. Instead, the question on whether the soils are: ***drained, lowland peat and peaty soils; Undrained, lowland peat and Upland blanket peat*** sets the context of soil drainage and erosion risk outcomes.

- ***Q. Are the soils freely, moderately, or poorly draining?*** – should be answered for non-extreme rainfall events and the combination of questions derives likelihood of runoff risks and the measures selection include some safety margin for risk.

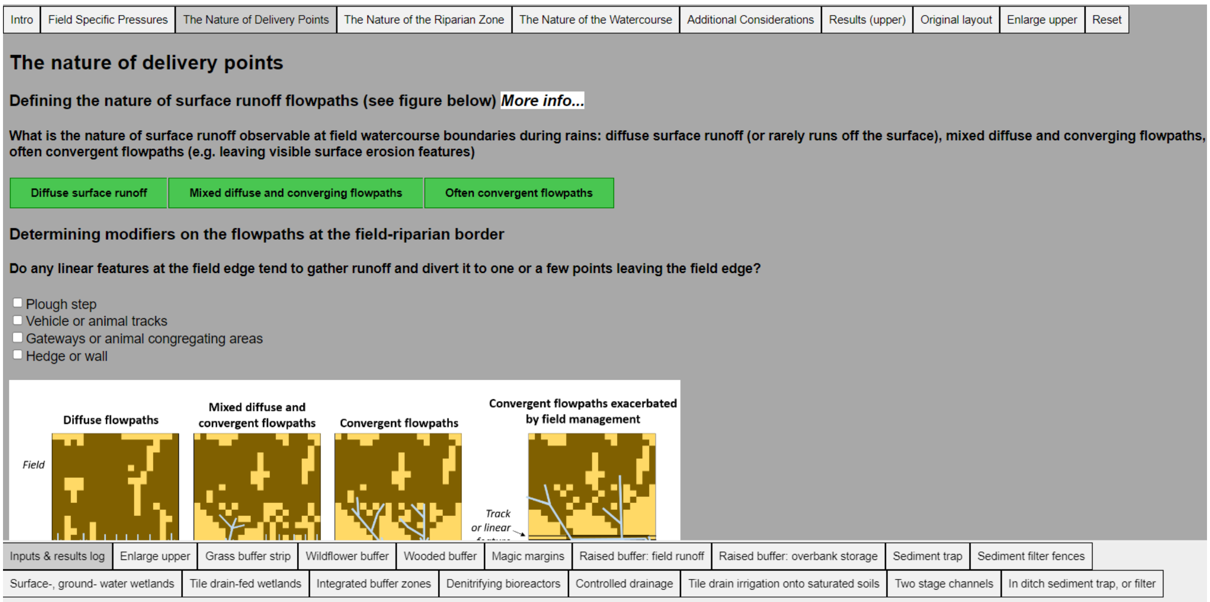
The question set prior to that of crop risk define inherent soil erosion risk classes, comprising: nine classes for mineral soils (three subclasses within each of high, medium and low), seven classes for lowland peats (low to moderate subdivisions) and one class (high) for upland blanket peat. The erosion risk class is based on work in Scotland by Lilly et al. (2002) using erosive energy (runoff and slope) and erodibility (based on texture for mineral soils and peat type for organic and peaty soils).

The next stage adjusts up/down the subdivisions of these inherent risk classes for the effects of cropping and land management with guidance notes provided.

A further stage acts to lower the erosion risk by one-two subdivisions if one, or more in-field mitigation measures are present.

4.2.2. The nature of delivery points

Figure 3. A section of the question input tab ***The Nature of Delivery Points***.



The questions here aim to define the extent that flow occurs diffusely across large parts of the soil surface (or beneath the surface) when it rains (such that linear general buffer zones are more appropriate) or often as convergent pathways of overland flow (where point sediment retention measures are more appropriate). A second question concerns modification of the flow paths by linear features on the field and guidance for both questions is provided in the form of a schematic.

- ***Q. Defining the nature of surface runoff flowpaths*** – should be answered generally from field observations across years of typical rainfall events, since it is likely that the most extreme events led to convergent flows in many situations.

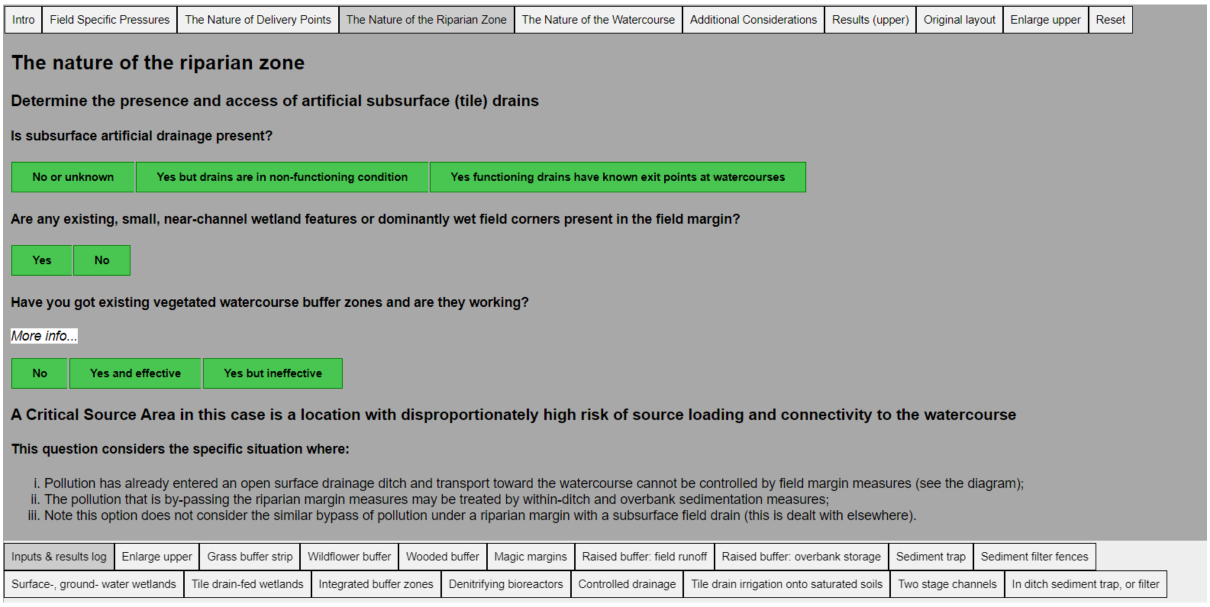
4.2.3. The nature of the riparian zone

Two questions in this section address important pathways known to bypass surface buffer zone management such as grass strips along the watercourse edge. Firstly, the occurrence of the key subsurface bypass pathway of artificial soil drainage is asked. This acts to prioritise the group of subsurface drain measures. Secondly, a very specific question addresses the occurrence of an open drainage ditch section that connects a high pollution source area of the field (CSA; Critical Source Area, e.g. an area of high soil nutrient content, area poached by cattle or another source area with high transport over/through soils) to the watercourse. Guidance on the latter is given by schematics.

- ***Q, Is artificial subsurface drainage present?*** – any of the yes questions trigger the consideration of artificial subsurface drainage measures and then site-survey should be used to ascertain condition, discharges and locations.
- ***Q, Does the situation of an open drainage ditch bypassing riparian management occur?*** – this has quite extensive guidance because of the very specific circumstance: A Critical Source Area in this case is a location with disproportionately high risk of source loading and connectivity to the watercourse. This question considers the specific situation where: (i) pollution has already entered an open surface drainage ditch and transport toward the watercourse cannot be controlled by field margin measures (see the diagram); (ii) the pollution that is by-passing the riparian margin measures may be treated by within-ditch and overbank sedimentation measures; (iii) note this option does not consider the similar bypass of pollution under a riparian margin with a subsurface field drain (this is dealt with elsewhere).

Other questions here address existing field edge grass margins and wet areas of margin space. The latter favours saturated ground features that have denitrification functions.

Figure 4. A section of the question input tab ***The Nature of the Riparian Zone***.

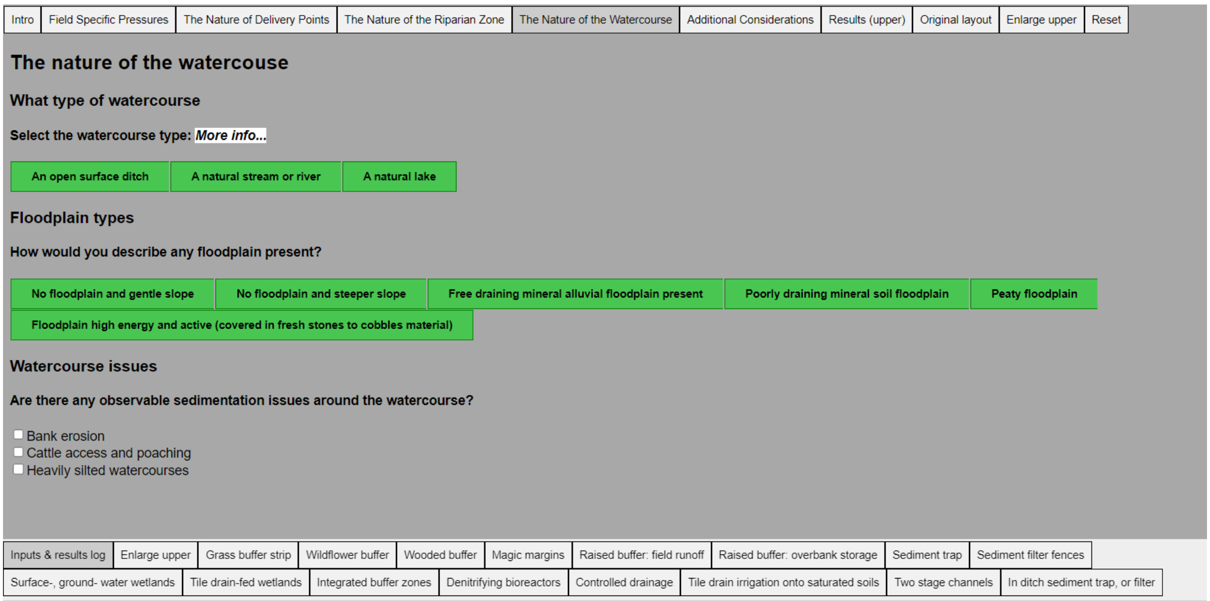


4.2.4. The nature of the watercourse

The first question on the watercourse type either allows in-ditch mitigation measures, or disallows them for a natural watercourse (see note below). Mitigation is considered similar for a lake as with a natural stream. The floodplain context is addressed here in a further question that allows differing combinations of drainage on the hillslope and floodplain. For example, freely draining soils on both hillslope and floodplain disallows saturated ground denitrification measures and leaves only measures that have low to moderate effectiveness for nitrate pollution. However, freely draining hillslope where nitrate may leach, if coupled to wet riparian zones and poor draining floodplains allow surface and ground water wetlands and saturated ground measures that increase nitrate mitigation effectiveness. A final question on specific watercourse issues related to sedimentation increases the weighting for sediment and total P retention measures.

- ***Q. Select the watercourse type*** – this has the following definitions in the pop-out guidance: An open surface ditch is man-made and can be generally distinguished from a natural stream by ditches being straightened, deepened, following field edges and corners with little relationship to natural landscape contours. However, natural streams may also be heavily engineered, but ditches never have an upstream stream waterbody (although may drain a lake). Any recommendations of in-ditch measures should be checked with relevant authorities.

Figure 5. A section of the question input tab ***The Nature of the Watercourse***.



4.2.5. Additional considerations

This tab does not affect the outcomes of the scoring and has no questions. Instead, it uses pop-outs to give guidance around three key aspects of habitat when considering components of riparian mitigation, their installation and management. The advice is generic without citing policy or regulation so that the tool is transferable between regions and is not date limited.

5. Rules for measure functioning versus landscape context

The rules within the tool are implemented by a multi-criteria master table (given here as Appendix section 9) and further look up tables for the erosion risk assessments (not shown here; referred to in section 4.2.1). When a question is answered the program checks the rule table for an indication of a criteria score (1-3) to build into the ranking for a given measure against others, or a zero. Where a zero occurs in any question outcome for a given measure that measure is disallowed (‘one out, all out’ rule).

The general logic behind the rule table is given in Table 2, below.

Table 2. Description of the rules for integrating the modes of operation of riparian pollution mitigation measures with the landscape attributes.

Measure group	Measure	Integration with dominant runoff pathways	Integration with hillslope or floodplain form and wetness	Other rules
Baseline margin space	**Grass buffer strip**	Effective up to moderate surface runoff; Ineffective at subsurface matrix flows and artificial drainage.	A flatter floodplain receiving zone makes these more effective, versus ineffective on steeper convex slopes.	
	Wildflower buffer	Effective up to moderate surface runoff; Ineffective at subsurface matrix flows and artificial drainage.	A flatter floodplain receiving zone makes these more effective, versus ineffective on steeper convex slopes.	
	Wooded buffer	Moderate effectiveness at subsurface leaching interception on hillslope and floodplains due to deep roots; Ineffective at artificial drainage by itself.	Increased roughness increases surface runoff effectiveness on moderately steep ground.	Unsuitable for peat soils on floodplains or hillslopes due to potential for soil carbon loss due to evapotranspiration lowering the watertable.
Surface runoff and sediment options	**Magic margins**	Effective at surface runoff and sedimentation. Ineffective at subsurface flows.	Can be used at the slope base on steeper ground. Requires moderate drainage at the slope base for infiltration, cannot be waterlogged.	First level augmentation of grass buffer, used in higher erosion risk situations of slope and cropping on soils that generate less runoff.
	Raised buffer: field runoff	Effective at surface runoff and sedimentation. Ineffective at subsurface flows and for freely draining soils.	Suitable to a greater range of soil wetness due to being a raised feature and outlet pipe can be engineered. May be built into moderately sloping banks.	Used in higher erosion risk situations of slope and cropping on soils that generate low-medium runoff. May be used in low erosion risk situations to manage flood risk. Combine with other drain options for artificially drained fields.

	Raised buffer: overbank storage	Effective at water storage and sedimentation from rising streamflow.	Suitable to a greater range of soil wetness due to being a raised feature and outlet pipe can be engineered.	Works in a catchment context to treat local and upstream runoff so may be suited to a location based on upstream, and not solely local risk, of runoff generation. Not suitable for steeply sloping banks as sited on floodplains.
	Sediment trap	Effective at surface runoff and sedimentation. Ineffective at subsurface flows and for free draining soils.	May be built into moderately sloping banks. Cannot be waterlogged or has no trapping capacity.	Mostly a measure for extreme erosion in other than poorly draining soils. Combine with other drain options for artificial drained fields.
	Sediment filter fences	Effective at aggressive situations of surface runoff and sedimentation. Ineffective at subsurface flows and for free draining soils.	Useful on steeper slopes where other measures are less suitable at aggressive erosion situations.	Considered a 'measure of last resort' for sediment control.
Sub-surface pathway options	**Surface-, ground-water wetlands**	Good for retaining surface- and ground- water for treatment, including effective for denitrification.	Only suitable for floodplain, shallow slope situations. Higher water tables required so less effective on artificially drained landscapes.	Suitable for high water table soils, especially peaty, where benefits C storage and C availability fuels denitrification. Appropriate on freely draining hillslopes where wet concave slope base or floodplain exists.
	Tile drain-fed wetlands	Intercepts tile drainage for wetland treatment e.g. denitrification. May intercept some groundwater if capacity designed well.	Only suitable for floodplain, shallow slope situations.	May be overwhelmed if receiving a lot of surface runoff.
	Integrated buffer zones	Multiple elements: (i) tile drain interception, (ii) soil matrix flow interception in bioactive tree root treatment zone, (iii) linear pond system capable of receiving surface runoff if managed.	Only suitable for floodplain, shallow slope situations. Designed for seasonally high watertables but may usefully intercept artificial drainage on a drier floodplain situation.	Tree planting should be excluded from peat soils due to soil carbon loss risks with lowered water table.

	Denitrifying bioreactors	Intercepts artificial drainage pathways to load bioreactor with nitrogen for treatment.	Only suitable for floodplain, shallow slope situations. Requires anaerobic wet conditions and high C but both can be engineered into a wider set of situations.	May be suitable for local tile drainage on floodplains if intercepts hillslope water to ensure sufficient loading.
	Controlled drainage	Intercepts artificial drainage pathways and holds water in an artificially wetted hillslope for certain seasons.	Requires correct gentle slope and riparian profiles to maintain saturated topsoils on a limited cropland area for winter seasons.	Requires large artificial subsurface drainage catchments extending up hillslopes. Farmer must be prepared for non-cultivation periods of low trafficking during time the drain valve is shut and soils wetted to avoid soil damage.
	Tile drain irrigation onto saturated soils	Irrigates tile drain water onto saturated surface soils for nitrogen treatment.	Only suitable for floodplain, shallow slope situations. Requires anaerobic wet conditions and moderate soil C levels.	
In-channel options	**Two stage channels**	Has multiple aspects of: (i) sedimentation and (ii) nitrogen processing in wet, secondary (side-benches) channel profile zones.	Requires fluctuation of river level from high to baseflow. Cannot work with high water table floodplains where stream height is maintained.	Works in a catchment context to treat local and upstream runoff so may be suited to a location based on upstream and not solely local pollution risks. Undrained wet floodplain situations are excluded. Can work with no floodplain if water table allows low stream flow.
	In ditch sediment trap, or filter	Functions for moderate to high risk erosion areas by providing sediment trapping in the channel.	Can work with a variety of slope forms and floodplain presence or not, or water tables adjacent to the channel suing different designs or trap or filter.	Works in a catchment context to treat local and upstream runoff so may be suited to a location based on upstream and not solely local erosion risks. Most suitable for high surface runoff areas. Unlikely sufficient sediment source area in freely drained landscapes.

6. Tool results outputs

The tool output recognises both the need to understand the landscape context at the field scale when selecting mitigation with differing models of action, but also that there will be needs to address known pollution issues with improvement goals at larger farm to catchment scales. Hence, the tool output is twofold:

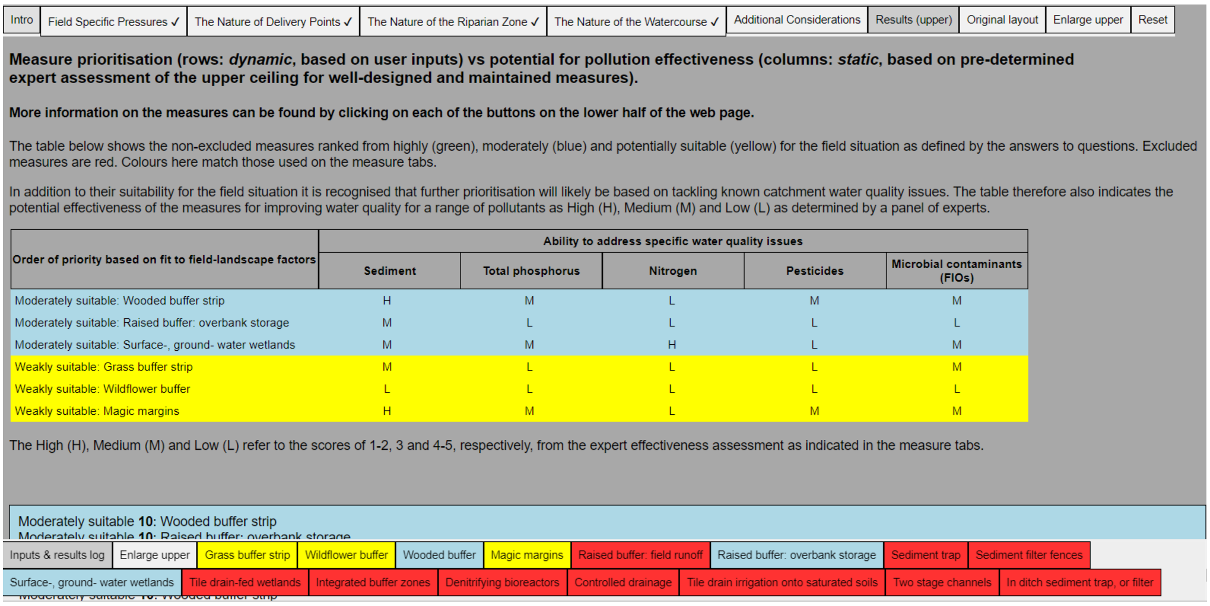
- Prioritisation between the sixteen mitigation measures is given through measures disallowed (red) and those placed in a ranking: weakly suited (yellow), moderately suited (blue) and well suited and targeted (green). These are informed by the rules in section 5 and respond dynamically to the user questions.
- A simple tabulation of the potential achievable effectiveness of well placed, designed and maintained measures for a range of pollutants as informed by the expert assessment process, reported here as static results i.e. the effectiveness does not vary with the question inputs (see section 3 for derivation and Appendix 9.2 for scores).

These outputs are given in the upper panel results table. Consistent colours for the ranking of measures are used between the results summary table and the colouration of each measure tab in the lower panel.

Examples of the results output tables are given (Figure 2) for (a) a free-draining arable field with nitrogen loss risks, and (b) an inherently poorly draining grassland field with artificial subsurface drainage. The links for the stored inputs and outputs of the tool are also given.

Figure 2. Example results output table showing mitigation ranking and the expert-informed effectiveness of the measures for different pollutants.

Example (a) is a free-draining arable field with nitrogen loss risks.



Intro | Field Specific Pressures ✓ | The Nature of Delivery Points ✓ | The Nature of the Riparian Zone ✓ | The Nature of the Watercourse ✓ | Additional Considerations | Results (upper) | Original layout | Enlarge upper | Reset

Measure prioritisation (rows: *dynamic*, based on user inputs) vs potential for pollution effectiveness (columns: *static*, based on pre-determined expert assessment of the upper ceiling for well-designed and maintained measures).

More information on the measures can be found by clicking on each of the buttons on the lower half of the web page.

The table below shows the non-excluded measures ranked from highly (green), moderately (blue) and potentially suitable (yellow) for the field situation as defined by the answers to questions. Excluded measures are red. Colours here match those used on the measure tabs.

In addition to their suitability for the field situation it is recognised that further prioritisation will likely be based on tackling known catchment water quality issues. The table therefore also indicates the potential effectiveness of the measures for improving water quality for a range of pollutants as High (H), Medium (M) and Low (L) as determined by a panel of experts.

Order of priority based on fit to field-landscape factors	Ability to address specific water quality issues				
	Sediment	Total phosphorus	Nitrogen	Pesticides	Microbial contaminants (FIOs)
Moderately suitable: Wooded buffer strip	H	M	L	M	M
Moderately suitable: Raised buffer: overbank storage	M	L	L	L	L
Moderately suitable: Surface-, ground- water wetlands	M	M	H	L	M
Weakly suitable: Grass buffer strip	M	L	L	L	M
Weakly suitable: Wildflower buffer	L	L	L	L	L
Weakly suitable: Magic margins	H	M	L	M	M

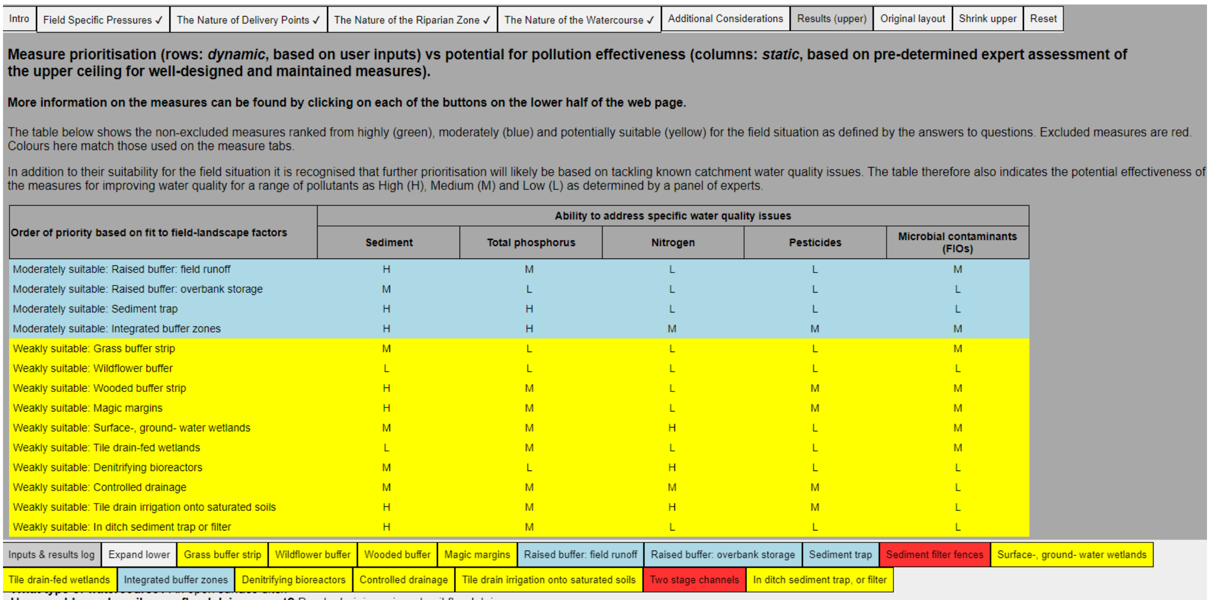
The High (H), Medium (M) and Low (L) refer to the scores of 1-2, 3 and 4-5, respectively, from the expert effectiveness assessment as indicated in the measure tabs.

Moderately suitable **10**: Wooded buffer strip

Inputs & results log | Enlarge upper | Grass buffer strip | Wildflower buffer | Wooded buffer | Magic margins | Raised buffer: field runoff | Raised buffer: overbank storage | Sediment trap | Sediment filter fences

Surface-, ground- water wetlands | Tile drain-fed wetlands | Integrated buffer zones | Denitrifying bioreactors | Controlled drainage | Tile drain irrigation onto saturated soils | Two stage channels | In ditch sediment trap, or filter

Example (b) is an inherently poorly draining grassland field with artificial subsurface drainage.



Intro | Field Specific Pressures ✓ | The Nature of Delivery Points ✓ | The Nature of the Riparian Zone ✓ | The Nature of the Watercourse ✓ | Additional Considerations | Results (upper) | Original layout | Shrink upper | Reset

Measure prioritisation (rows: *dynamic*, based on user inputs) vs potential for pollution effectiveness (columns: *static*, based on pre-determined expert assessment of the upper ceiling for well-designed and maintained measures).

More information on the measures can be found by clicking on each of the buttons on the lower half of the web page.

The table below shows the non-excluded measures ranked from highly (green), moderately (blue) and potentially suitable (yellow) for the field situation as defined by the answers to questions. Excluded measures are red. Colours here match those used on the measure tabs.

In addition to their suitability for the field situation it is recognised that further prioritisation will likely be based on tackling known catchment water quality issues. The table therefore also indicates the potential effectiveness of the measures for improving water quality for a range of pollutants as High (H), Medium (M) and Low (L) as determined by a panel of experts.

Order of priority based on fit to field-landscape factors	Ability to address specific water quality issues				
	Sediment	Total phosphorus	Nitrogen	Pesticides	Microbial contaminants (FIOs)
Moderately suitable: Raised buffer: field runoff	H	M	L	L	M
Moderately suitable: Raised buffer: overbank storage	M	L	L	L	L
Moderately suitable: Sediment trap	H	H	L	L	L
Moderately suitable: Integrated buffer zones	H	H	M	M	M
Weakly suitable: Grass buffer strip	M	L	L	L	M
Weakly suitable: Wildflower buffer	L	L	L	L	L
Weakly suitable: Wooded buffer strip	H	M	L	M	M
Weakly suitable: Magic margins	H	M	L	M	M
Weakly suitable: Surface-, ground- water wetlands	M	M	H	L	M
Weakly suitable: Tile drain-fed wetlands	L	M	L	L	M
Weakly suitable: Denitrifying bioreactors	M	L	H	L	L
Weakly suitable: Controlled drainage	M	M	M	M	L
Weakly suitable: Tile drain irrigation onto saturated soils	H	M	H	M	L
Weakly suitable: In ditch sediment trap or filter	H	M	L	L	L

Inputs & results log | Expand lower | Grass buffer strip | Wildflower buffer | Wooded buffer | Magic margins | Raised buffer: field runoff | Raised buffer: overbank storage | Sediment trap | Sediment filter fences | Surface-, ground- water wetlands

Tile drain-fed wetlands | Integrated buffer zones | Denitrifying bioreactors | Controlled drainage | Tile drain irrigation onto saturated soils | Two stage channels | In ditch sediment trap, or filter

7. Tool general functions and utility

The following aspects have been designed into the tool to increase utility:

Exit tool – returns to the website entry page.

Measure description tabs – these contain a summary of the mitigation measures considered in the tool (see section 3, this report) laid out in a consistent format and including the summary of expert effectiveness for a range of pollutants and wider benefits.

Shrink / enlarge upper – resizes the upper panel to favour greater space to view the lower panel of mitigation measure descriptions (goes back to default of 50/50 sizing).

Maximise upper / Original layout – resizes upper to fill whole page to enable the upper results table to be read more clearly, or when inputting to questions.

Shrink / enlarge lower – resizes the lower panel to favour more space to view the upper panel of question inputs and main results table. Note that for both the default function is a 50/50 split of space between upper versus lower.

Guidance pop-outs – these are used whenever the designers and testers felt that more info was required on a question's concepts or terminology and usually appears by hovering the cursor on 'more info'. Some diagrammatic guidance is given to explain diffuse versus convergent flow path classifications and the specific concept of a Critical Source Area bypassing a riparian buffer zone by an open drainage ditch.

Storage of inputs and outputs – the lower panel tab 'Results' gives the summarised inputs to questions and at the bottom of this area is a generated, unique weblink to an archived version of the tool as completed at that point with all measure rankings and outputs and inputs stored.

Reset – clears all entries to allow the user to start afresh.

Iterative variation of inputs – once the inputs have been completed and a results table is generated the user can go back into any question sections and change one or several answers, then compare the changes in the results table. For example, this could include increasing the severity of runoff and erosion in the ***field specific pressures tab***, or switching on subsurface artificial drain pathways in the ***nature of the riparian zone tab***.

8. References

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Appendix 9.1. Criteria scoring table for weighting and excluding the measures against questions. Numerical values per row denote measure exclusion (zero) or a positive score into the summed overall score. Questions result in one outcome row per group (field specific pressures only), or individual question (all others).

		Question group outcomes	Grass buffer strip	Wildflower buffer	Wooded buffer	Magic margins	Raised buffer: field runoff	Raised buffers: overbank storage	Sediment traps	Buffer surface and ground water wetlands	Tile drain fed wetlands	Integrated buffer zones	Denitrifying bioreactor	Controlled drainage	Tile drain irrigation onto saturated soils	Sediment filter fence	Two-stage channels	In-ditch sediment trap or filter
Field specific pressures	Question group: Q. Is the soil mineral or peaty?; Q. Are the soil freely, moderately, or poorly draining; Q. Are hillslopes flat, gentle, moderate, steep or very steep slopes?; Q. Is soil texture clay, loamy, sandy?; Q (peats only), Is the peaty soil lowland drained, lowland undrained or blanket upland peat?; Q, Crop classes that modify inherent topsoil erosion risks?; Q, In field mitigation measures that modify the erosion risk class?	L erosion risk, low runoff	3	3	2	1	1	1	1	**2**	0	**1**	2	0	0	0	1	1
		M erosion risk, low runoff	1	1	2	2	2	2	2	**2**	0	**1**	2	0	0	0	2	1
		H erosion risk, low runoff	0	0	1	2	2	2	2	**2**	0	1	2	0	0	2	2	2
		L erosion risk, mod-high runoff	1	1	1	1	1	1	1	**2**	2	1	1	2	2	0	1	1
		M erosion risk, mod-high runoff	2	2	2	1	1	1	1	**2**	2	2	1	2	2	0	1	1
		H1 erosion risk, mod-high runoff	0	0	2	1	2	2	2	2	2	2	0	1	2	1	1	2
		H2-3 erosion risk, mod-high runoff	0	0	1	2	2	2	2	2	2	1	0	1	2	2	1	2
		L erosion risk, peaty soils	1	1	0	0	1	1	0	1	2	1	0	1	1	0	1	0
		M erosion risk, peaty soils	2	2	0	0	2	2	0	2	2	1	0	1	1	1	1	1
Nature of delivery points	Q, What is the nature of surface runoff?	Diffuse surface runoff	2	2	2	**1**	0	**1**	0	2	2	2	2	2	2	0	1	1
		Mixed diffuse and convergent flowpaths	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	2
		Often convergent flowpaths	0	0	1	**0**	2	2	2	1	1	2	1	1	1	2	1	2
	Q, Do any linear features at the field edge modify flow?	Selection of any of the listed modifiers	1	1	1	2	2	2	2	1	1	1	1	1	1	2	1	1
Subsoil drains	Q, Is artificial subsurface drainage present?	Not present/unknown	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1
		Yes present (any of the 2 yes options)	1	1	1	1	1	1	1	1	3	3	3	3	3	1	1	1
Wet areas	Q, Any existing near-channel wetland features or dominantly wet field corners in the margin?	Yes	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**1**	**2**	**1**	**1**	**1**
Existing Veg strips	Q, Any existing grass buffer zone features and are they working?	Yes and effective	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
		Yes but ineffective	**1**	**1**	**1**	**2**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**
CSA bypass	Q, Is an open drainage ditch bypassing buffer zones?	Yes	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	3
Watercourse type	Q, Select the watercourse type	Yes to natural stream, river or lake	1	1	2	1	1	2	1	2	1	1	1	1	1	1	1	0
Floodplain types	Q, How would you describe any floodplain present?	No floodplain, sloping directly to banks (a) look at slope Q = slope <10°	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
		No floodplain, sloping directly to banks (b) look at slope Q = slope >10°	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	1
		Freely draining mineral alluvial floodplain	1	1	2	2	2	2	2	0	0	1	1	1	1	1	2	1
		Poorly draining mineral soil floodplain	1	1	2	1	2	2	2	3	3	3	1	1	2	1	0	1
		Peat-dominated floodplain	1	1	0	0	1	1	1	3	2	0	0	0	1	0	0	0
		High energy floodplain	1	1	1	0	0	0	1	1	1	0	1	1	1	0	0	0
Watercourse sedimentation	Q, Any observed sedimentation issues around watercourses?	Yes to any	1	1	2	2	3	3	3	1	1	2	1	1	1	1	2	3

Appendix 9.2. Scores for potential (upper ceiling for well designed, sited and maintained measures) pollutant effectiveness used in the reporting table of the tool against the dynamic (ie user question-derived) ranking of measures according to landscape suitability. (a) Original 1 (low) to 5 (high) effectiveness scores from the first level of scoring by 24 international experts (response rate 32% to a questionnaire) and (b) a simplification of the results used in the tool report table using a low (L), medium (M) and high (H) classification.

(a)

	sediment	phosphorus	nitrogen	pesticide	FIO
Grass buffer strip	3	2	1	2	3
Wildflower buffer strip	2	2	2	2	2
Wooded buffer strip	4	3	2	3	3
Magic margin	4	3	2	3	3
Raised buffer: field runoff	4	3	2	2	3
Raised buffer: overbank storage	3	2	2	1	2
Sediment trap	4	4	2	2	2
Sediment filter fence	4	3	1	1	2
Surface-, groundwater- wetland	3	3	4	2	3
Tile drain-fed wetland	2	3	3	2	3
Integrated buffer zone	4	4	3	3	3
Denitrifying bioreactor	3	2	4	2	2
Controlled drainage	3	3	3	3	2
Tile drain irrigation onto saturated soil	4	3	4	3	2
Two-stage channels	4	3	3	2	2
In-ditch sediment trap, or filter	4	3	2	2	2

(b)

	sediment	phosphorus	nitrogen	pesticide	FIO
Grass buffer strip	M	L	L	L	M
Wildflower buffer strip	L	L	L	L	L
Wooded buffer strip	H	M	L	M	M
Magic margin	H	M	L	M	M
Raised buffer: field runoff	H	M	L	L	M
Raised buffer: overbank storage	M	L	L	L	L
Sediment trap	H	H	L	L	L
Sediment filter fence	H	M	L	L	L
Surface-, groundwater- wetland	M	M	H	L	M
Tile drain-fed wetland	L	M	M	L	M
Integrated buffer zone	H	H	M	M	M
Denitrifying bioreactor	M	L	H	L	L
Controlled drainage	M	M	M	M	L
Tile drain irrigation onto saturated soil	H	M	H	M	L
Two-stage channels	H	M	M	L	L
In-ditch sediment trap, or filter	H	M	L	L	L