A decision tool to help protect fish stocks in a targeted reach following a river re-start

To navigate through the tool, click on the underlined text

Begin

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Agree

Is this a managed flow?

Yes

No

Return to start

Can the flow be delayed until somewhere between mid-autumn and mid-spring?

Yes

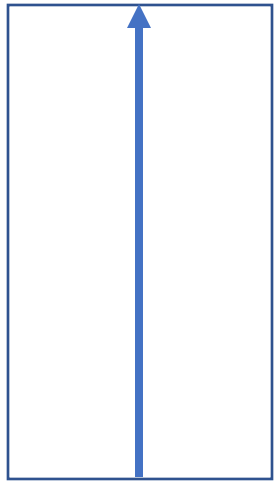
No

Return to start

If at all possible it is recommended that the flow be delayed until the air and water temperatures are cooler. The reason is that many of the drivers of hypoxia are mediated by temperature. The higher the water temperature, the more likely an hypoxic event will occur. Fish kills caused by planned flows should be avoided.

Return to start

Is water still flowing in the target reach?



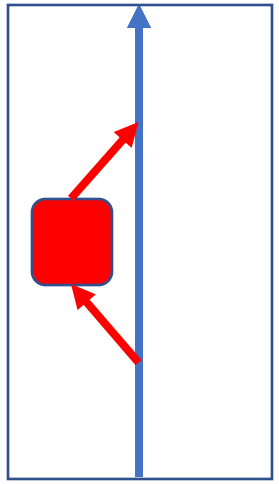
A still flowing main channel

Yes

No

Return to start

Is water expected to go out onto the floodplain?

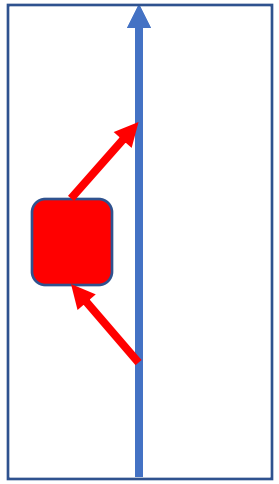


Yes

No

Return to start

Is water expected to go out onto the floodplain?

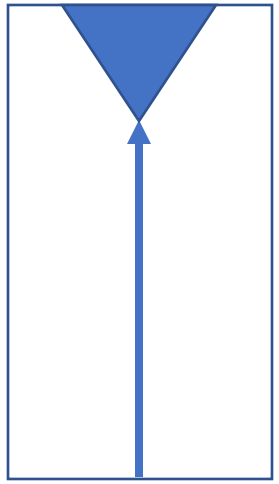


Yes

No

Return to start

Is the target reach a weir pool or other impoundment?



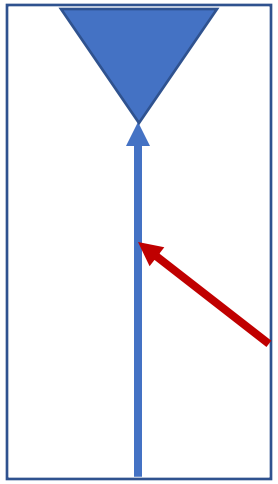
A still flowing main channel with d/s weir pool as the target reach

Yes

No

Return to start

Is there a significant dry tributary or tributaries upstream of the weir pool?*



Inflow from previously dry tributary or tributaries into a still flowing main channel with a d/s weir pool

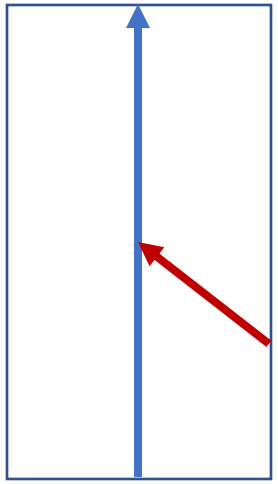
Yes

No

Return to start

* Will the inflows from the dry tributary or tributaries following a rainstorm be approximately the same, or greater, than is currently flowing in the main channel? If so, the dry channels upstream will be considered significant.

Is there a significant dry tributary or tributaries upstream of the target reach?*



Inflow from previously dry tributary or tributaries into a still flowing main channel with a d/s weir pool

Yes

No

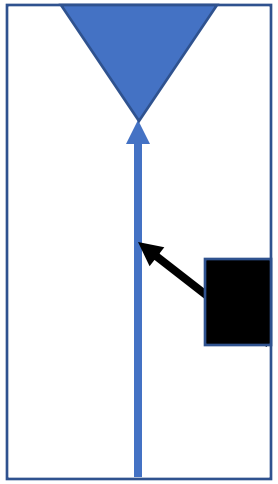
Return to start

* Will the inflows from the dry tributary or tributaries following a rainstorm be approximately the same, or greater, than is currently flowing in the main channel? If so, the dry channels upstream will be considered significant.

There is little risk of hypoxia at the target reach at the current time. Continue to monitor dissolved oxygen in the target reach and assess any changes in condition that could lead to the onset of hypoxia (see Baldwin, 2021).

Return to start

Have there been recent fires in the upper catchment?



Yes

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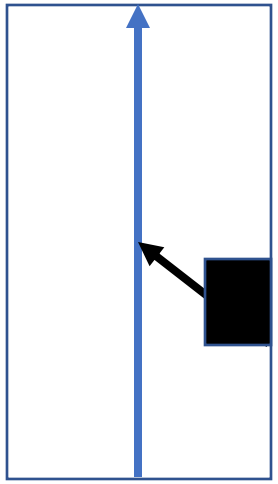
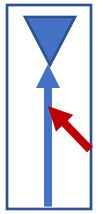


Yes

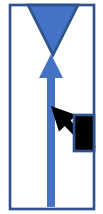
No

The fish population in the weir pool may be at risk from hypoxia caused by destratification in the weir pool and from hypoxic inflows from upstream. Assess the risk from potential destratification first then the risk of hypoxia from upstream sources



Return to start

The fish population in the weir pool may be at risk from hypoxia caused by destratification in the weir pool and from hypoxic inflows. Assess the risk from potential destratification first then from inflows contaminated by fire residue.



Return to start

Can you measure the oxygen profile throughout the water column in the weir pool at a number of locations.

Yes

No

Is the dissolved oxygen concentration at the bottom of the weir pool < 3 mg/L?

< 3mg/L

> 3mg/L

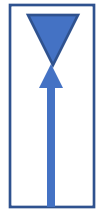
Return to start

There is a heightened risk of hypoxic throughout the water column following destratification of the weir pool. Destratification can be caused either by increased inflows or, a cool change. The impact of destratification on dissolved oxygen concentration in the water column needs to be assessed

Action: Use the tool for predicting hypoxia in a pool following destratification to estimate the dissolved oxygen in the weir pool following mixing.

Predicted dissolved oxygen concentration is <3 mg/L

Predicted dissolved oxygen concentration is >3 mg/L



Return to start

There is little risk of hypoxia throughout the water column caused solely by destratification of the weir pool. However, there may be other sources of hypoxia from upstream

Continue to next question

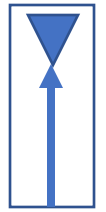
Return to start

Can’t measure DO concentration profile throughout the water column

Without an assessment of the dissolved oxygen profile throughout the water column it is not possible to quantify the risk of hypoxia posed by potential increased flows (or the arrival of a cool change). In the absence of actual data, risk could be estimated through an assessment of previous fish kills in this reach. Specifically has a fish kill been recorded in this weir pool that corresponded either to an increase in flows from a low flow base, or alternatively following a cool change. It is suggested that **a communication plan** be prepared for stakeholder engagement in the event of a fish kill.

Continue to next question

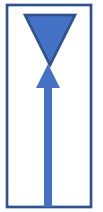
Return to start



There is a significant risk of a fish kill occurring in the weir pool caused by hypoxia following destratification. The lower the predicted dissolved oxygen concentration following destratification the higher the risk.

Is the weir structure undershot?

Yes **No**

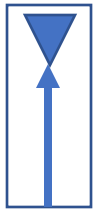


Return to start

Draining the hypolimnion

- One successful strategy applied in the Murrumbidgee River in 2019 was to drain the hypolimnion water from the weir pool. The undershot gates were opened and the hypoxic hypolimnion water flowed downstream The hypoxic water was naturally re-aerated downstream through atmospheric exchange. The extent of downstream re-aeration can be estimated using the **Dilution Module** in the Blackwater Intervention Assessment Tool .
- Deployment of aerators in the weir pool is also a potential intervention, however they only operate over a quite small spatial scale (10 – 100's metres).

Continue to next question



Creating local aerated refuges

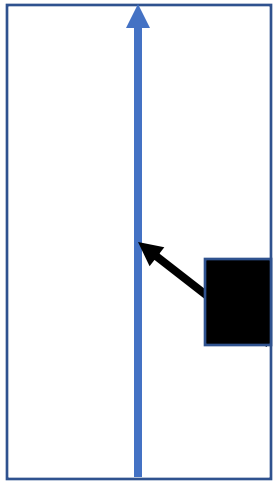
Local refuges can be created using aerators. Venturi aerators are more effective than bubble plume or paddle-type aerators in shallow river environments (weir pools, residual pools or slow-flowing reaches of rivers). Even then, they are only effective in maintaining an oxic zone from 10's – 100's metres from the aerator. They can be difficult to deploy at short notice, and will require an energy source (typically a diesel aerator).

If threatened or endangered species are present, or species with unique genetic make-up, **translocation** to a safe environment should be considered.

A **communication plan** should be prepared in advance highlighting the heightened risk of a fish kill occurring in the zone.

Return to start

Have there been recent fires in the upper catchment?



Yes

No

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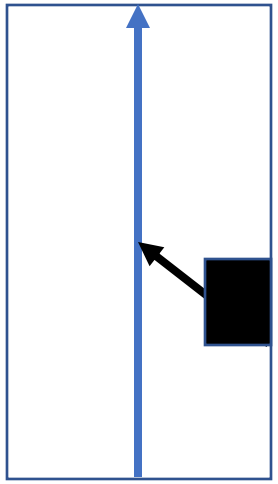
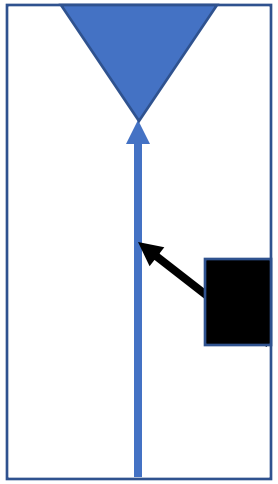


Yes

No

Is this the first or second major inflow from the fire field since the fire?



Yes

No

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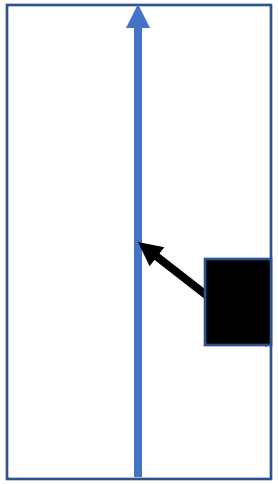
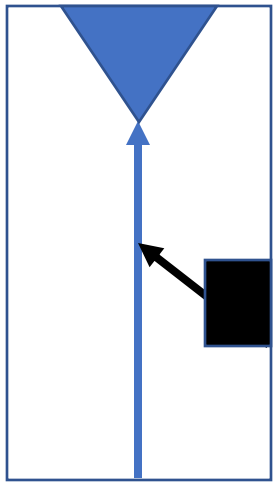
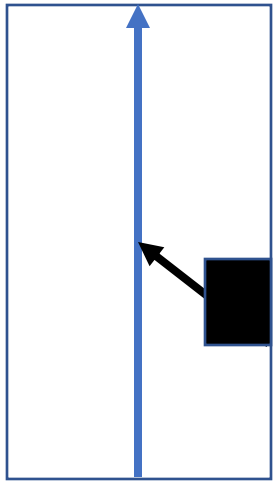


Yes

No



The risk of hypoxia from bush fire residue is diminished, but not completely gone. Monitor dissolved oxygen concentrations in the target reach and consider potential interventions



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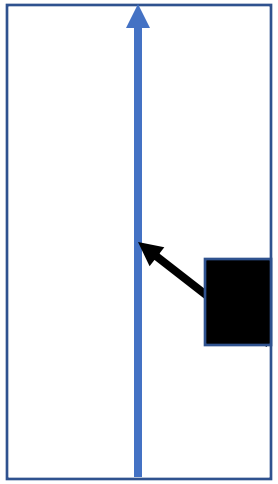
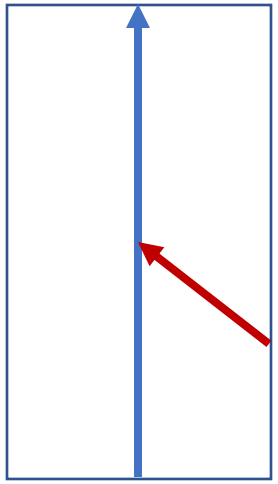


There is a real risk of hypoxia from bush fire residue . Explore potential interventions to prevent hypoxia in the target reach

Flowing channel as target reach; hypoxic risk from inflows from previously dry tributary or tributaries



Inflow from a previously dry tributary or tributaries into a still-flowing main channel

Assessing the risk: How does the current flow in the main channel (F_M) compare to the flow that is (or could potentially come) from the previously dry tributary or tributaries (F_T).

$F_M >> F_T$

$F_M \sim F_T$

$F_M < F_T$

Return to start

$F_M >> F_T$

- The risk of hypoxia in the main channel is low when the inflow from the tributaries are substantially smaller than the main channel assuming that the dissolved oxygen concentration in the main channel is well oxygenated).
- There may be a localised zone of hypoxia at the junction, but fish would probably be able to move away from the zone.
- The approximate dissolved oxygen on mixing water from tributaries with short residence times (*ca*. a day) with the main channel can be estimated using the **Tributary Contribution to DO Tool**.
- For tributaries with longer residence times (days – weeks) assume the inflow into the main channel will be anoxic ([DO] = 0 mg/L for at least two days and use the **Dilution Module** in the **Blackwater Intervention Tool** to estimate the dissolved oxygen concentration on mixing.
- It is recommended that the dissolved oxygen concentrations downstream of the confluence be monitored.

Return to start

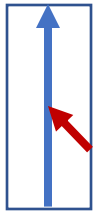
$F_M \sim F_T$

- The risk of hypoxia in the main channel is difficult to determine *a priori* as it will will depend on factors such as the dissolved oxygen concentration in the main channel, the amount of litter in the dry tributaries and the water temperature.
- The approximate dissolved oxygen on mixing water from tributaries with short residence times (*ca*. a day) with the main channel can be estimated using the **Tributary Contribution to DO Tool**.
- For tributaries with longer residence times (days – weeks) assume the inflow into the main channel will be anoxic ([DO] = 0 mg/L for at least two days and use the the **Dilution Module** in the **Blackwater Intervention Tool** to estimate the dissolved oxygen concentration on mixing. **Intercepting the hypoxic water** before it reaches the main channel should be considered
- If the models indicate potential hypoxia in the main channel then an assessment of **Intervention Options** is strongly recommended.

Return to start

$F_M < F_T$

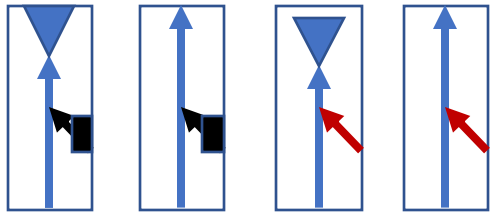
- The risk of hypoxia in the main channel is difficult to determine *a priori,* but is likely; especially if the inflow occurs in the period from late spring to early autumn.
- The approximate dissolved oxygen on mixing water from tributaries with short residence times (*ca*. a day) with the main channel can be estimated using the **Tributary Contribution to DO Tool**..
- For tributaries with longer residence times (days – weeks) assume the inflow into the main channel will be anoxic ([DO] = 0 mg/L for at least two days and use the **Dilution Module** in the **Blackwater Intervention Tool** to estimate the dissolved oxygen concentration on mixing. **Intercepting the hypoxic water** before it reaches the main channel should be considered.
- An assessment of **Intervention Options** is strongly recommended.



Intervention Options: Dilution Flows

Is there an upstream source of water that can be released that will dilute the hypoxic inflow?

Yes **No**

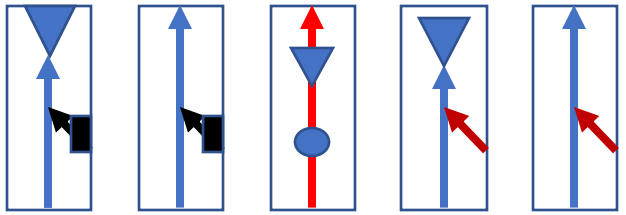


Intervention Options: Intercepting the hypoxic flow front

Is there enough water-pump capacity along the river reach to effectively remove the first two days of flow along the reach?*

Yes **No**

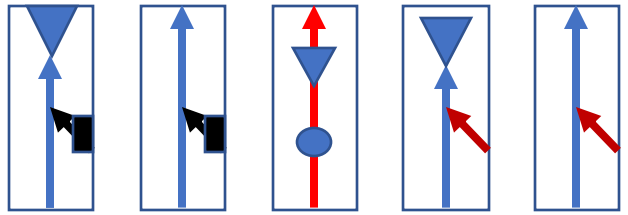
*As an indication, a single 12” irrigation pump can displace something of the order of 10ML/day. In most circumstances the pumping option is probably limited to total flows of less than about 200 ML/day.



Using Irrigation Infrastructure

- In this approach the hypoxic flow front is pumped out of channel.
- Once the dissolved oxygen concentration in the water at the flow front reaches 4-6 mg/L, pumping ceases and the flow front is allowed to pass downstream.
- In flows going down previously dry channels, more than one point of intervention may be necessary, as the flow front may once more become hypoxic.
- Ideally, appropriate sites are identified, and arrangements are made to use the irrigation infrastructure as a contingency, well before it is needed.
- It is likely that regulatory approval will need to be arranged to harvest the flow front.

Explore other potential interventions



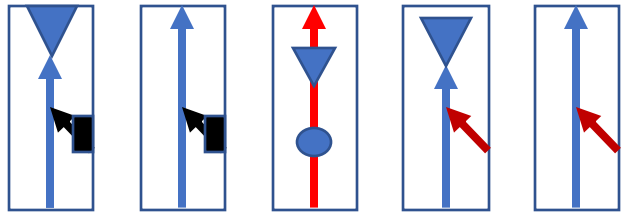
Intervention Options: Off-River Diversion

Is there a suitable site or sites along the channel to divert the first approximately two days of the flow front away from the river channel. Suitable sites could include dry wetlands (especially if controlled by regulators), irrigation channels, dry deflation basin lakes, or off-river water storages*.

Yes **No**

Return to start

*If the off-river water storages contain water, ensure that there is sufficient water currently in the storage to prevent extensive hypoxia following flow diversion



Dilution flows

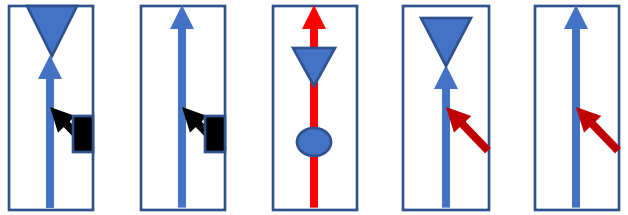
- Because the main channel is still flowing, it implies that there is an upstream source of water, which is regulated.
- In assessing whether or not to use a dilution flow determine how much water is required? An assessment of the volume of water required to prevent hypoxia at the confluence can be estimated from the **Dilution Module** of the **Blackwater Intervention Tool**. However, bear in mind that the inflow will most likely contain reactive carbon and therefore the dissolved oxygen concentration will continue to fall downstream of the confluence.
- Water travel time is also an important consideration. It is highly likely that a dilution flow would need to be pre-emptively released to be effective. This could be based on, for example, predicted rainfall in the catchment (see REF for an example). Noting rainfall predictions are usually only accurate up to about 5 days in advance.

Explore other potential interventions

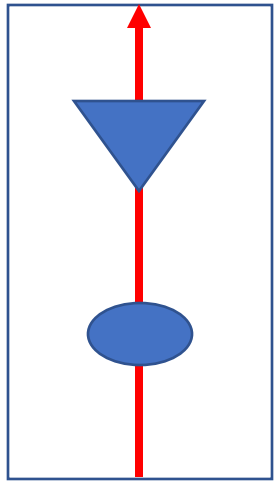
Off-River Diversion

- To be effective, the diversion to the off-river storage must be able to intercept the flow front preventing its progression downstream.
- As a general rule the off-takes into such storages are located some distance above the bottom of the river channel.
- they tend to work best where there is already a standing body of water (e.g. a weir pool) or where the channel is still flowing
- For dry reaches adjacent to water off takes it may be possible to install a temporary barrier (e.g. block bank) to allow the water to reach the outlet level.

Explore other potential interventions



Isolated pools (including weir pools) scattered along a dry river channel



The river reach has reduced to a series of isolated pools, either natural or constructed.

The fish communities in isolated pools are at potential risk from three sources –

- Hypoxia developing in the pool from litter fall
- Hypoxic inflows from upstream
- Hypoxia following destratification once the flow front reaches the pool.

Assessing the Risks

Return to start

Intervention Options: Intercepting the hypoxic flow-front

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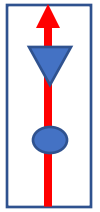

Using Pumping Infrastructure

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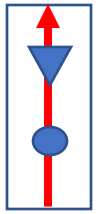
Explore other interventions



Intervention Options: Off River Diversion

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Yes **No**

Return to start

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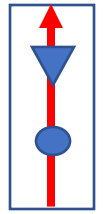

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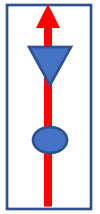
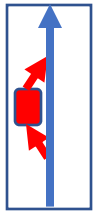


Explore other interventions

Has overbank flows (flooding) commenced?

Yes

No



Return to start

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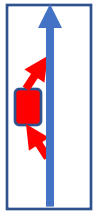
Yes

No



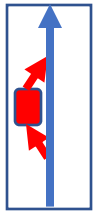
Return to start

Action: Run the Blackwater Risk Assessment Tool (or equivalent)

Based on the results of modelling, will the flood-return water lead to either hypoxia or anoxia in the receiving channel?

Yes **No**

Return to start



Action: Run the Blackwater Risk Assessment Tool (or equivalent)

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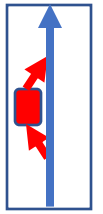
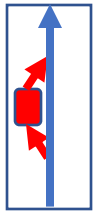
Yes **No**

Return to start



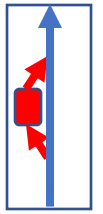
Re-consider the managed flood

The risk of hypoxia resulting in fish deaths downstream is high. If at all possible the planned flood should be delayed until the period from mid-autumn until mid-spring. If it is not possible to stop the planned flood, then contingency planning should be undertaken to determined potential **Interventions** to limit potential fish deaths.



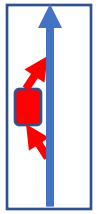
Monitor the main channel to assess dissolved oxygen concentrations. If dissolved oxygen concentrations in the main channel fall below about 3 - 3.5 mg/L start assessing potential management interventions.

Return to start



Can you measure dissolved oxygen concentrations in the flood water near the point where it is expected to return to the main channel?

Yes **No**

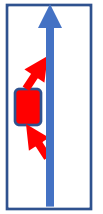


Action 1: Determine dissolved oxygen concentrations in the flood water on the floodplain.

Action 2: Run the Dilution Module in the Blackwater Intervention Assessment Tool to estimate the dissolved oxygen concentration in the main channel following return of the flood water

Will the main channel be anoxic or hypoxic following return of the flood water?

Yes **No**

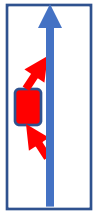


Interventions: Floodplain Inundation

Practically there are two types of interventions that can be used to minimise the impact of hypoxic water following a significant overbank flooding:

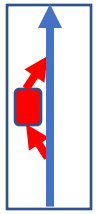
Diversion of the hypoxic return water into a large, shallow off-river storage

Creation of local aerated refuges



Diversion into a large, shallow off river storage

In this intervention the hypoxic return water is diverted into a large, shallow off-river storage. The hypoxic water is re-oxygenated by prolonged exposure to the atmosphere, aided by wave action and seiching. The oxygenated water is then returned to the main channel. The storage needs to be large enough to store at least a week of flow (and probably much longer). In practice, there will only be one or two locations on most rivers that would be suitable for this type of intervention (e.g. Lakes Tandure and Pamamaroo on the Darling River, Lake Victoria on the Murray River). Therefore suitable sites should be identified *a priori*. The **Lake Wind Aeration** module in the **Blackwater Intervention Assessment Tool** can be used to assist in planning.

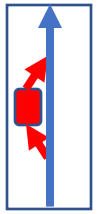


Return to Intervention options page

Creating local oxygenated-refuges

Will the floodwater in the main channel cascade over a structure like a weir?

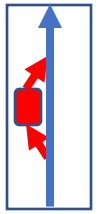
Yes **No**



Flow over structure

Flow over structures has the potential to create an oxygenated zone immediately downstream of the structure. The extent of the refuge can be estimated using the **Flow Over Structure** module in the **Blackwater Intervention Assessment Tool.**

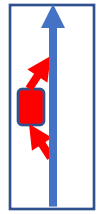
Return to Creating Oxygenated Refuges page



Are there tributaries or irrigation outfalls that can be used to deliver oxygenated water to the main channel?

Yes

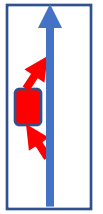
No



Oxygenated Flows

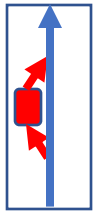
Unlike dilution flows, the purpose of these inflows is to create an oxygenated zone in the main channel adjacent to an oxygenated inflow – a tributary or irrigation outfall. Because the inflows will need to be maintained for a period of time (potentially months) a large volume of water will need to be secured. Turning off the inflow prior to cessation of hypoxic in the main channel could potentially lead to fish deaths. Furthermore, if itis physically possible, fish will likely move into the outfall and will risk stranding if the outfall flow ceases.

Return to Creating Oxygenated Refuges page



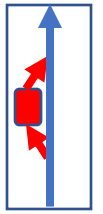
Are there sites along the main channel which are connected to the main channel at flood water levels but have limited water exchange with the main channel (e.g. large backwaters, low lying wetlands or marina's)?

Yes **No**



As translocation of fish from the main channel during a flood would be logistically difficult, and would pose a real risk to the health of personnel undertaking the task, the only option is to recognise that there will be a fish kill and prepare a **communication plan** to inform relevant stakeholders.

Return to start



Blackwater Risk Assessment Tool

The Blackwater Risk Assessment Tool (BRAT) is an excel-based tool which predicts the dissolved oxygen concentration in the main channel following floodwater return. A copy of the tool can be downloaded from *Rivers and Wetlands* web page.

Download BRAT

Note: odels using the algorithms underlying BRAT, but with a more sophisticated (site-specific) treatment of floodplain hydrology are being developed by external parties.

Return to start

Blackwater Intervention Assessment Tool

The Blackwater Intervention Assessment Tool (BIAT) is an excel-based tool used to determine the effectiveness or otherwise of three approaches to mitigating the impacts of hypoxic blackwater:

- Dilution flows
- Flows over structures
- Lake Wind aeration.

The model was developed specifically for managing hypoxia caused by overbank flows, but can be used in other instances.

Download Blackwater Intervention Assessment Tool

Return to start

Predicting hypoxia following destratification

As part of the “Rivers Restart” project, a simple tool was developed to predict the dissolved oxygen throughout the water column following destratification based on dissolved oxygen concentrations measured throughout the water column. The tool can process up to 20 measurements, but it is important that measurements are made throughout the water column, including immediately above the sediments. The tool contains a number of simplifying assumptions, nevertheless, the approach has proved to be useful in a number of rivers in the Murray-Darling Basin.

Download the Predicting Hypoxia Following Destratification tool

Return to start

Tributary Contribution to DO Tool

This is a simplified version of the Blackwater Risk Assessment Tool developed specifically for the “River Restart” Project. It is applicable for short tributaries with a water travel-time from headwaters to the junction of the main channel of about 1 day. Note the The tool is a currently a beta version and has not been validated in the field.

Download the Tributary Contribution to DO tool

Return to start

Manage any identified risk. For further details on interventions see Baldwin (2021) a copy of which is available Here

Return to start

Creating local aerated refuges

Local refuges can be created using aerators. Venturi aerators are more effective than bubble plume or paddle-type aerators in shallow river environments (weir pools, residual pools or slow-flowing reaches of rivers). Even then, they are only effective in maintaining an oxic zone from 10's – 100's metres from the aerator. They can be difficult to deploy at short notice, and will require an energy source (typically a diesel aerator).

If threatened or endangered species are present, or species with unique genetic make-up, **translocation** to a safe environment should be considered.

A **communication plan** should be prepared in advance highlighting the heightened risk of a fish kill occurring in the zone.

Continue

Is the flow occurring somewhere between mid-autumn and mid-spring

Yes

No

Are there salt intrusions or saline pools (with water column salinities greater than about 2500 EC) in the water course?

Yes

No

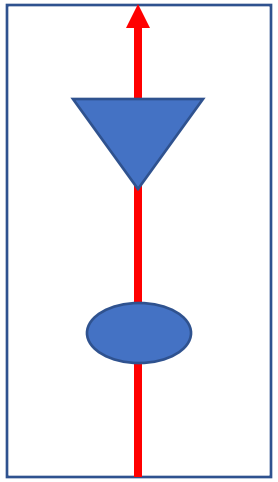
Risk of acid sulfate soils

There is a risk that there are acid sulfate soils in the water course. If they are disturbed they can strip oxygen out of the water column (as well as substantially lowering the pH and release heavy metals – for more information on acid sulfate soils in inland waterways click here).

It is recommended that an assessment for the presence of acid soils in the channel be undertaken.

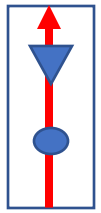
Return to start

Can you measure the oxygen profile throughout the water column in the pool (at a number of locations if it is a weir pool).



Yes

No

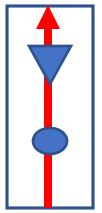


Can’t measure DO concentration profile throughout the water column

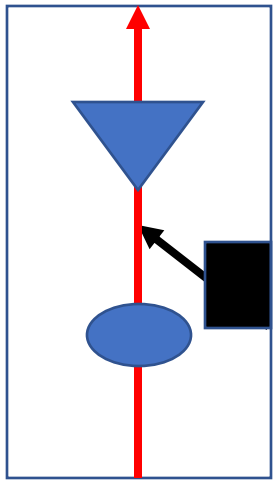
Without an assessment of the dissolved oxygen profile throughout the water column it is not possible to quantify the risk of hypoxia posed by potential increased flows (or the arrival of a cool change). In the absence of actual data, risk could be estimated through an assessment of previous fish kills in this reach. Specifically has a fish kill been recorded in this weir pool that corresponded either to an increase in flows from a low flow base, or alternatively following a cool change. It is suggested that **a communication plan** be prepared for stakeholder engagement in the event of a fish kill.

Continue to next question

Return to start



Have there been recent fires in the upper catchment?



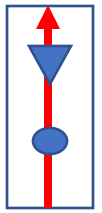
Yes

No

Preparing for inflows

Flows along dry river channels can lead to hypoxia because carbon is mobilised both from litter that has accumulated in the channel as well as carbon in the dry sediment. In the absence of any additional information it is assumed that the flow front will by hypoxic. Interventions should be considered.

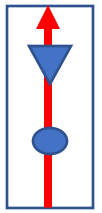
Interventions



Preparing for inflows

There is a high likelihood that the flow front will be hypoxic because it will contain carbon from the fire field as well as carbon from the dry river channel. Interventions are strongly recommended to prevent fish deaths in the target reach.

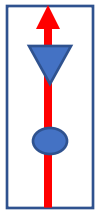
Interventions



Is the dissolved oxygen concentration at the bottom of the pool < 3 mg/L?

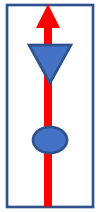
< 3mg/L

> 3mg/L



Return to start

The risk of hypoxia from destratification is currently low, but may become worse over time through litter inputs from riparian vegetation and oxygen demand from the sediments. If there is extensive overhanging trees or there has been a history of fish kills at the site previously, consider install an aerator or aerators. Otherwise, continue to monitor the pool, and prepare for managing inflows.



Creating local aerated refuges

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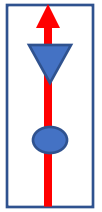
If threatened or endangered species are present, or species with unique genetic make-up, **translocation** to a safe environment should be considered.

In addition to installing aerators in the pool, other intervention strategies should be considered for managing the inflows.



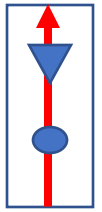
Preparing for inflows

There is a heightened risk of hypoxic throughout the water column following destratification of the pool. Destratification can be caused either by increased inflows or, a cool change. The impact of destratification on dissolved oxygen concentration in the water column needs to be assessed

Action: Use the tool for predicting hypoxia in a pool following destratification to estimate the dissolved oxygen in the weir pool following mixing.

Predicted dissolved oxygen concentration is <3 mg/L

Predicted dissolved oxygen concentration is >3 mg/L



Return to start