Pump stations for flood harvesting or irrigation downstream of a storage dam

A technical report from the CSIRO Victoria and Southern Gulf Water Resource Assessments for the National Water Grid

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Important disclaimer

CSIRO Victoria and Southern Gulf Water Resource Assessments acknowledgements

This report was funded through the National Water Grid's Science Program, which sits within the Australian Government's Department of Climate Change, Energy, the Environment and Water.

Aspects of the Assessments have been undertaken in conjunction with the Northern Territory and Queensland governments.

The Assessments were guided by three committees:

1. The Governance Committee: CRC for Northern Australia/James Cook University; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Agriculture and Fisheries; Queensland Department of Regional Development, Manufacturing and Water
2. The joint Roper and Victoria River catchments Steering Committee: Amateur Fishermen's Association of the NT; Austrade; Centrefarm; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Cattlemen's Association; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; NT Farmers; NT Seafood Council; Office of Northern Australia; Parks Australia; Regional Development Australia; Roper Gulf Regional Council Shire; Watertrust
3. The Southern Gulf catchments Steering Committee: Amateur Fishermen's Association of the NT; Austral Fisheries; Burketown Shire; Carpentaria Land Council Aboriginal Corporation; Health and Wellbeing Queensland; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Prawn Fisheries; Queensland Department of Agriculture and Fisheries; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Regional Development, Manufacturing and Water; Southern Gulf NRM

Responsibility for the Assessments' content lies with CSIRO. The Assessments' committees did not have an opportunity to review the Assessments' results or outputs prior to their release.

This report was reviewed by Cuan Petheram (CSIRO).

Acknowledgement of Country

CSIRO acknowledges the Traditional Owners of the lands, seas and waters of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture and pay our respects to their Elders past and present.

Photo

'Flood lifter' with diesel drive on the Flinders River, Queensland. Source: CSIRO

Director’s foreword

Sustainable development and regional economic prosperity are priorities for the Australian, Queensland and Northern Territory (NT) governments. However, more comprehensive information on land and water resources across northern Australia is required to complement local information held by Indigenous Peoples and other landholders.

Knowledge of the scale, nature, location and distribution of likely environmental, social, cultural and economic opportunities and the risks of any proposed developments is critical to sustainable development. Especially where resource use is contested, this knowledge informs the consultation and planning that underpin the resource security required to unlock investment, while at the same time protecting the environment and cultural values.

In 2021, the Australian Government commissioned CSIRO to complete the Victoria River Water Resource Assessment and the Southern Gulf Water Resource Assessment. In response, CSIRO accessed expertise and collaborations from across Australia to generate data and provide insight to support consideration of the use of land and water resources in the Victoria and Southern Gulf catchments. The Assessments focus mainly on the potential for agricultural development, and the opportunities and constraints that development could experience. They also consider climate change impacts and a range of future development pathways without being prescriptive of what they might be. The detailed information provided on land and water resources, their potential uses and the consequences of those uses are carefully designed to be relevant to a wide range of regional-scale planning considerations by Indigenous Peoples, landholders, citizens, investors, local government, and the Australian, Queensland and NT governments. By fostering shared understanding of the opportunities and the risks among this wide array of stakeholders and decision makers, better informed conversations about future options will be possible.

Importantly, the Assessments do not recommend one development over another, nor assume any particular development pathway, nor even assume that water resource development will occur. They provide a range of possibilities and the information required to interpret them (including risks that may attend any opportunities), consistent with regional values and aspirations.

All data and reports produced by the Assessments will be publicly available.

C. Chilcott

Chris Chilcott

Project Director

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Shortened forms

SHORT FORM	FULL FORM
EL	elevated level
HDPE	high-density polyethylene
NT	Northern Territory

Units

UNIT	DESCRIPTION
m^3	cubic metre
kW	kilowatt
L	litre
ML	megalitre
m	metre

Preface

Sustainable development and regional economic prosperity are priorities for the Australian, NT and Queensland governments. In the Queensland Water Strategy, for example, the Queensland Government (2023) looks to enable regional economic prosperity through a vision which states 'Sustainable and secure water resources are central to Queensland's economic transformation and the legacy we pass on to future generations.' Acknowledging the need for continued research, the NT Government (2023) announced a Territory Water Plan priority action to accelerate the existing water science program 'to support best practice water resource management and sustainable development.'

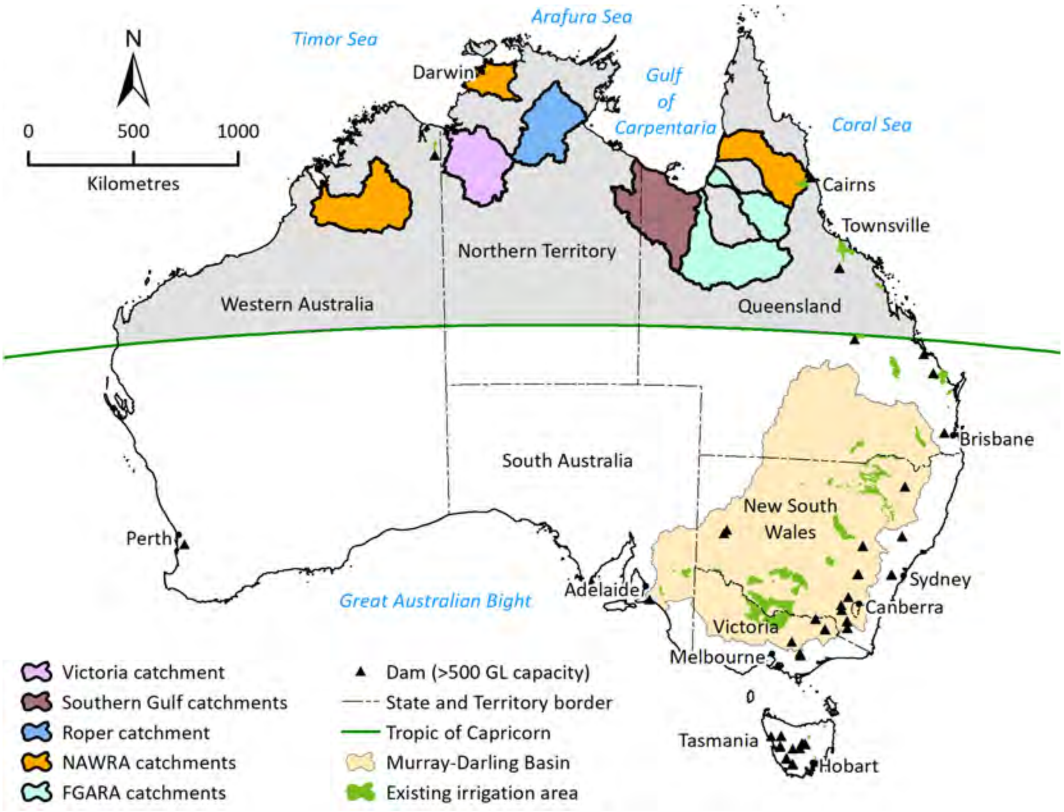
Governments are actively seeking to diversify regional economies, considering a range of factors, including Australia's energy transformation. The Queensland Government's economic diversification strategy for north west Queensland (Department of State Development, Manufacturing, Infrastructure and Planning, 2019) includes mining and mineral processing; beef cattle production, cropping and commercial fishing; tourism with an outback focus; and small business, supply chains and emerging industry sectors. In its 2024–25 Budget, the Australian Government announced large investment in renewable hydrogen, low-carbon liquid fuels, critical minerals processing and clean energy processing (Budget Strategy and Outlook, 2024). This includes investing in regions that have 'traditionally powered Australia' – as the North West Minerals Province, situated mostly within the Southern Gulf catchments, has done.

For very remote areas like the Victoria and Southern Gulf catchments, the land (Preface Figure 1-1), water and other environmental resources or assets will be key in determining how sustainable regional development might occur. Primary questions in any consideration of sustainable regional development relate to the nature and the scale of opportunities, and their risks.

How people perceive those risks is critical, especially in the context of areas such as the Victoria and Southern Gulf catchments, where approximately 75% and 27% of the population (respectively) is Indigenous (compared to 3.2% for Australia as a whole) and where many Indigenous Peoples still live on the same lands they have inhabited for tens of thousands of years. About 31% of the Victoria catchment and 12% of the Southern Gulf catchments are owned by Indigenous Peoples as inalienable freehold.

Access to reliable information about resources enables informed discussion and good decision making. Such information includes the amount and type of a resource or asset, where it is found (including in relation to complementary resources), what commercial uses it might have, how the resource changes within a year and across years, the underlying socio-economic context and the possible impacts of development.

Most of northern Australia's land and water resources have not been mapped in sufficient detail to provide the level of information required for reliable resource allocation, to mitigate investment or environmental risks, or to build policy settings that can support good judgments. The Victoria and Southern Gulf Water Resource Assessments aim to partly address this gap by providing data to better inform decisions on private investment and government expenditure, to account for intersections between existing and potential resource users, and to ensure that net development benefits are maximised.



Preface Figure 1-1 Map of Australia showing Assessment areas (Victoria and Southern Gulf catchments) and other recent CSIRO Assessments

FGARA = Flinders and Gilbert Agricultural Resource Assessment; NAWRA = Northern Australia Water Resource Assessment.

The Assessments differ somewhat from many resource assessments in that they consider a wide range of resources or assets, rather than being single mapping exercises of, say, soils. They provide a lot of contextual information about the socio-economic profile of the catchments, and the economic possibilities and environmental impacts of development. Further, they consider many of the different resource and asset types in an integrated way, rather than separately.

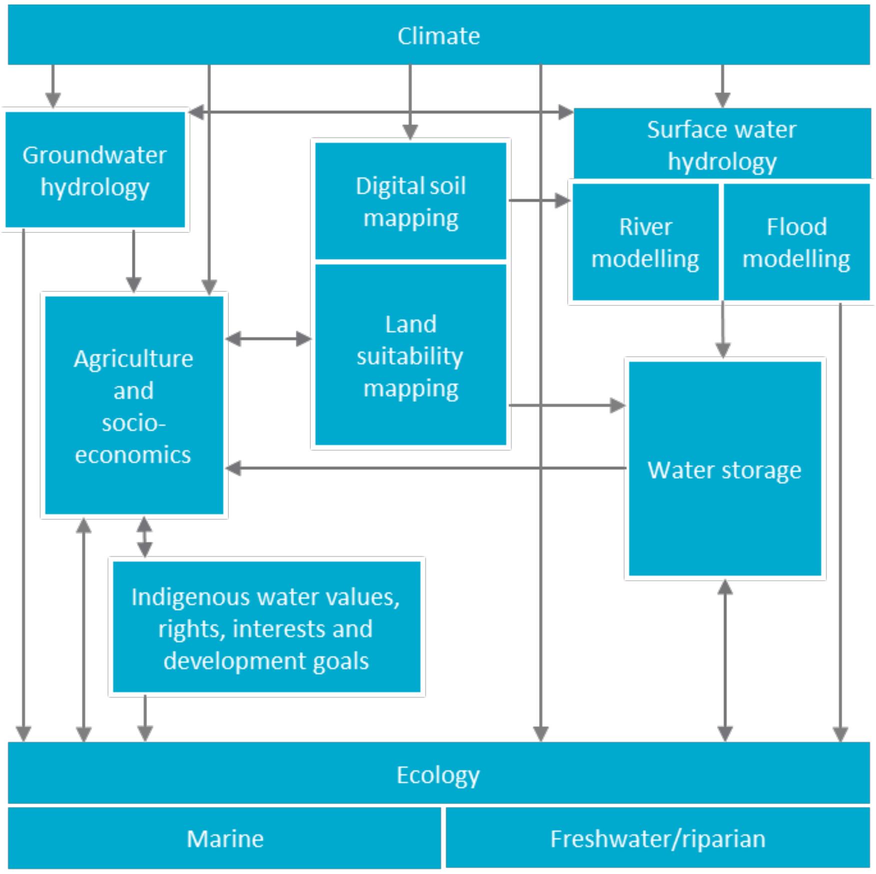
The Assessments have agricultural developments as their primary focus, but they also consider opportunities for and intersections between other types of water-dependent development. For example, the Assessments explore the nature, scale, location and impacts of developments relating to industrial, urban and aquaculture development, in relevant locations. The outcome of no change in land use or water resource development is also valid.

The Assessments were designed to inform consideration of development, not to enable any particular development to occur. As such, the Assessments inform – but do not seek to replace – existing planning, regulatory or approval processes. Importantly, the Assessments do not assume a given policy or regulatory environment. Policy and regulations can change, so this flexibility enables the results to be applied to the widest range of uses for the longest possible time frame.

It was not the intention of – and nor was it possible for – the Assessments to generate new information on all topics related to water and irrigation development in northern Australia. Topics not directly examined in the Assessments are discussed with reference to and in the context of the existing literature.

CSIRO has strong organisational commitments to Indigenous reconciliation and to conducting ethical research with the free, prior and informed consent of human participants. The Assessments allocated significant time to consulting with Indigenous representative organisations and Traditional Owner groups from the catchments to aid their understanding and potential engagement with their requirements. The Assessments did not conduct significant fieldwork without the consent of Traditional Owners.

Functionally, the Assessments adopted an activities-based approach (reflected in the content and structure of the outputs and products), comprising activity groups, each contributing its part to create a cohesive picture of regional development opportunities, costs and benefits, but also risks. Preface Figure 1-2 illustrates the high-level links between the activities and the general flow of information in the Assessments.



Preface Figure 1-2 Schematic of the high-level linkages between the eight activity groups and the general flow of information in the Assessments

Assessment reporting structure

Development opportunities and their impacts are frequently highly interdependent and, consequently, so is the research undertaken through these Assessments. While each report may be read as a stand-alone document, the suite of reports for each Assessment most reliably informs discussion and decisions concerning regional development when read as a whole.

The Assessments have produced a series of cascading reports and information products:

- Technical reports present scientific work with sufficient detail for technical and scientific experts to reproduce the work. Each of the activities (Preface Figure 1-2) has one or more corresponding technical reports.
- Catchment reports, one for each of the Victoria and Southern Gulf catchments, synthesise key material from the technical reports, providing well-informed (but not necessarily scientifically trained) users with the information required to inform decisions about the opportunities, costs and benefits associated with irrigated agriculture and other development options.
- Summary reports, one for each of the Victoria and Southern Gulf catchments, provide a shorter summary and narrative for a general public audience in plain English.
- Summary fact sheets, one for each of the Victoria and Southern Gulf catchments, provide key findings for a general public audience in the shortest possible format.

The Assessments have also developed online information products to enable users to better access information that is not readily available in print format. All of these reports, information tools and data products are available online at https://www.csiro.au/victoriariver and https://www.csiro.au/southerngulf. The webpages give users access to a communications suite including fact sheets, multimedia content, FAQs, reports and links to related sites, particularly about other research in northern Australia.

Executive summary

This report discusses factors affecting pump station design. The report is not intended as a design manual but rather an examination of the factors that would determine the optimum characteristics for pump stations for those particular situations.

Flood-harvesting pump installations are typically axial flow pumps located on a suitable section of river bank, with minimal surrounding infrastructure and with the motors above normal flood range. Motive power for the pump/s can be electric if distribution networks allow, but like most locations across northern Australia, motive power would usually be supplied by diesel power pack in the Victoria and Southern Gulf catchments.

A preliminary estimate of the installed cost of a pump and rising main and power pack can be gained from a multiple of the duty flow and head, using a value of $30,000 to $40,000 per cubic metre per second per metre of total lift.

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1 Introduction

This report discusses factors affecting pump station design and complements the Northern Australia Water Resource Assessment technical report on farm-scale dam design and costs (Benjamin, 2018), which examined aspects of the design and costs of ring-tanks and gully dams but did not explicitly discuss pumping stations. This report is not intended as a design manual for those installations but rather an examination of the factors that would determine the optimum characteristics for pump stations for those particular situations.

Specifically, this report is focused on the design and costs of pumping stations for flood water harvesting applications and pumping water from re-regulating structures, such as weirs. Note that flood harvesting in this context refers to the diversion of water from any flow above a defined starting flow rate or starting level, as determined on the relevant authorising licence.

A typical flood-harvesting installation or an installation to pump from a re-regulating structure would involve the following elements:

- Re-regulating structure. While this will normally not be required for a typical ‘flood-harvesting’ installation, since the starting flow conditions (imposed by the licence terms) would normally mean a relatively high river stage when pumping, it becomes relevant for those applications involving releases from a proposed dam upstream. Its purpose is primarily to provide sufficient submergence for the pump intake to function at start-up without damage cavitation.
- The pump unit. Normally an axial flow pump, described further below for its high-volume low-head characteristics, with the barrel laid directly on the river bank with minimal foundations, sufficient to hold the pump at high river stages. The barrel will be of sufficient length to put the drive mechanism above normal flood level.
- The power unit. For typically flood harvesting operations, this will be located at a bend in the pump body and will feature an angled drive to either an electric or diesel power unit.
- Rising main. The pump body will transition to a pipe rising main as soon as practical, normally driven by pipe embedment considerations. That is, the pipe must be anchored, and suitably embedded to resist loads such as traffic and backfill loads.
- Outfall structure. The rising main will normally terminate in either a distribution channel, or directly to a ringtank storage. In both cases, a non-return valve, such as a flap valve is necessary to control loss back down the pump conduit.

2 Pump station considerations

While each installation will be unique in terms of its physical, hydrological and geological setting, some guidelines can be presented that will point towards the type of development appropriate to each situation. These are discussed under the following headings:

- Design standard
- Dry or wet well installation
- Power source
- Type of pump unit
- Rising main sizing
- Potential for transient pressure issues
- Water conditioning issues.

In each case, the comparative advantages of each type of installation with respect to either group supply schemes or large-scale water harvesting operations will be discussed. Finally, the development of costing functions for preliminary estimation of the cost of these installations will be discussed.

2.1 Design standard

The standard to which a pump station is built is often related to the risk and consequence of failure. For example, a pump station that supplies multiple high-value enterprises may be built to a higher standard than a pump station supplying water to a single low-value enterprise where the consequence of failure may be internally managed. For the former installation, a higher standard would be necessary, so it would be required to operate during high-flow events in the river, and potentially during flows where the bed sediments will be mobilised. Sole operation installations, by contrast, may be able to tolerate being out of action during high-flow events or power failures. Mechanically, they may be less robust, and may be housed in structures where some minor damage on a regular basis will be tolerated.

2.2 Dry or wet well installation

Dry or wet well installation refers to the types of housing for the physical pump unit(s). This can be either ‘dry’, which means that the pumps are not in direct contact with the river water, or wet, where the pump unit is either underwater or subject to wetting at high river flows. In general, the former is more applicable to larger installations, especially those requiring high-voltage power supply, and the latter is more applicable to smaller installations. The pump enclosure performs a number of functions other than merely housing the pump. It also provides the ability to condition the water by removing debris and in some cases bed load from the water column, provides a safety function to stop any of the larger forms of wildlife being drawn into the pump units, and provides the necessary stability to resist flood-event forces.

Typically, high-standard installations will be concrete structures that are anchored to the bedrock, but lower standard installations will typically only be anchored to slab foundations, or in many cases being comprised of steel sheet piling. In some, admittedly rare cases, pumps might be on a floating structure, to eliminate the need for any fixed foundations. These types are sometimes also found in dam impoundments (Julius and Eungella dams feature these).

2.3 Power source

This refers to the energy source for the pump units. In practically all cases this will come down to a choice between electricity and diesel for the above-mentioned situations. See companion technical report on renewable energy supply in the Victoria and Southern Gulf catchments (Hayward, 2024).

Diesel powered pump stations typically consume about 0.25 to 0.3 L of diesel per kWh of energy input to the pumping unit. Depending on the effective cost of diesel, this will be well above the equivalent cost of an electrically powered installation. However, for electric to be a practical option, the cost of providing reticulated power to the installation must be considered. For most pump installations where the need for pumping is intermittent and the cost of power reticulation is prohibitive, diesel would be the most cost-effective. A number of factors need to be considered to determine the most appropriate source of power including:

- available diesel subsidies
- the ongoing cost of diesel motor maintenance and replacement
- the available electricity tariffs
- the initial contribution required for the electricity reticulation upgrades required
- the total energy demand and pattern of demand. Very small, and/or highly intermittent demand may not be practical to connect to the electricity grid.

In particular circumstances, the possibility may exist to supply an electrically driven installation by solar, rather than reticulated grid power. Such an arrangement would of course have to tolerate the intermittent nature of the power source. This does not tend to apply to flood-harvesting opportunities, which are not tolerant of power outages during pumping windows. See companion technical report on renewable energy in the Victoria and Southern Gulf catchments (Hayward, 2024).

2.4 Type of pump unit

For the above applications, only rotodynamic pumps need be considered. The other classes of pumps, being reciprocating or rotary positive displacement pumps, do not have application for the typical large flow moderate head use for flood harvesting.

There are three general types of rotodynamic pumps: radial, mixed flow and propeller pumps. Each is discussed below. A comment is included on specific speed (Equation 1), as this is the defining characteristic of the different impellor types. Specific speed is calculated as:

$$N_s = nq^{1/2}/h^{3/4} \quad (1)$$

where:

- 'N_s' is specific speed (dimensionless)
- 'n' is pump rpm
- 'q' is flow in m^3/second
- 'h' is system head in metres.

Radial or centrifugal pumps

- Power requirement increases with flow; head vs flow curve is relatively flat, and maximum efficiency occurs near or just below maximum head.
- Can operate in zero-flow condition for start-up and shutdown.
- Specific speed is between 25 and 70.

Mixed-flow pumps have Francis-type impellors

- Power requirement increases slightly with flow; head vs flow curve is generally sloping downwards gently from shut-off conditions.
- Maximum efficiency is towards higher flows, and well below shut-off head capacity.
- Can operate in zero-flow conditions for start-up and shutdown.
- Specific speed is between 70 and 160.

Propeller pumps or axial flow pumps

- Power requirement and head capacity decrease steeply with increasing flow.
- Maximum efficiency is at a low-head, high-flow position.
- Most do not tolerate zero flow without serious cavitation.
- In irrigation applications, these are normally mounted on the river bank with minimal foundations. The pump body forms the inlet and part of the rising main.
- Specific speed is between 140 and 400.

For all cases, the power consumed by the pump is given by the following (Equation 2):

$$kW = L/second \times m/(102.04 \times \mu) \quad (2)$$

where:

- 'kW' is the power input required
- 'm' is the total head, including static lift, pipe friction and velocity head
- 'µ' is the pump efficiency.

As a general rule, propeller-type pumps are best suited to high-volume low-head (typically less than 10 m) applications at lesser efficiency, and radial pumps are best suited to higher heads (typically above 10 m) and higher efficiency. Mixed-flow applications tend to be in the middle, but lend themselves mostly to high flow at moderate head applications. The above comments refer only to single stage applications, and those applications overlap, so consideration must be given to a range of types for any situation.

In Australia, the most common type of axial flow pumps are those manufactured by Batescrew and Ornel. Both are New South Wales firms, the former in Tocumwal, and the latter in Griffith.

For mixed-flow pumps, the range is larger, with a variety of quality levels. Major suppliers are DPS, Macquarie and KSB.

Radial pumps are supplied by a large range of suppliers, with the most common being Flygt submersibles and KSB.

Both mixed-flow and radial pumps are able to operate in multiple stage pumps for higher head applications, but these are not commonly used for water harvesting operations. Axial flow pumps can also be multi-staged, but this is also not common for the heads being considered here.

2.5 Rising main sizing

A key issue in pump station design is the selection of the optimum-sized rising main. For the applications being considered, this will be the connection between the pump unit in the river and the start of the reticulation to the served area. Note that in some cases, this will involve supply to a second pump point where filtration and re-pumping for delivery by pivots or low-pressure spray occurs. In any event, the required length of the rising main will be determined primarily by existing topography and the vertical lift to the lands to be irrigated. Since the rising main will normally discharge into either a carrier channel, or directly to a ringtank storage, and represents a high-cost element of the overall scheme, the total cost of the system will be minimised if the rising main is as short as possible.

Pipe diameter and length, and to a lesser extent pipe material, is the major determinant of the friction component of the total head on the pump. The process to optimise the diameter selection then becomes a matter of minimising the sum of the following cost components:

- pump station capital cost
- rising main capital cost
- outlet works capital cost
- pump station energy cost, amortised to a net present value.

It can be seen that the above items will all change with varying pipe diameters. It is also true that there are other variable operational costs. However, the sensitivity of those to changes in pipe diameter is small, and for the purpose of the optimisation analysis, they can be ignored. It must be stressed, however, that the above analysis is only for pipeline diameter optimisation and is not relevant for project viability studies.

2.6 Potential for transient pressure issues

The potential for transient pressure issues implies that rising mains, especially those involving high pipe velocities and long rising main lengths, are potentially prone to severe water hammer surge issues. These can be either high- or low-pressure surges, and typically occur when the pump suddenly stops (for example in a power failure) or in an uncontrolled start-up or sudden closure of an in-line valve. While the positive surges can normally be handled by selection of a suitable pipe class, the negative pressures are more difficult to deal with. Negative pressures can also result in cavitation in the pipeline, which will either lead to collapse of the pipe or very high transient pressures when the separated columns of water rejoin. Pipelines where surge issues are possible need to be carefully analysed and the appropriate mitigation measures incorporated into the design. The following guidelines provide a preliminary indication of the potential for water hammer surge issues:

- Rising mains less than 100 m long, and with pipe velocities less than 2.5 m/second, are unlikely to have surge issues that cannot be adequately handled by the selection of pipe class based on pump shut-off head. The main reason is that the pump run-down time is likely to be well clear of the critical water hammer period.
- Rising mains with lengths over 1000 m and velocities over 2.5 m/second are almost certain to have issues with water hammer surges and will require some specific protective devices. Typical measures are one-way surge tanks to limit negative surges, and surge valves to bleed over-pressure events.
- Rising mains that do not meet these conditions will have the potential for surge issues and will need to be assessed on an individual basis.

2.7 Water conditioning issues

The topic of water conditioning covers a number of issues, depending on the actual environment. As outlined above in the section on wet/dry well installation, there is a minimum need to provide some screening to protect against debris ingress and to provide a safety function. Depending on the quality of the water, especially for those installations designed to work during high-stage flood events, there may also be a requirement to remove sediment load from the water due to unacceptable wear and tear to the pump unit. This has been found to be an issue on easterly draining large rivers in Queensland, where peak irrigation demand for a downstream irrigation area that is experiencing dry weather can correspond to a major flood event caused by heavy rain in a distant upstream part of the catchment. Even if the demand is not high, the flood event, if it is sufficiently large to cause bed mobilisation, has the potential to effectively ‘drown’ the pump station in silt.

There is no one simple answer to this issue, but some solutions that have worked include:

- Having the pumps in a sealed box, where the front inlet can be closed by a bulkhead during bed-mobilising flood events. (This option is used with most Burdekin River pumps, and some pump stations on Pioneer River.) This of course precludes the operation of that station during those events.

- Designing the flow inlet in a flowing river to be a particular spiral that deposits entrained sands and silt due to Coriolis forces. (Mirani Pump Station on the Pioneer River is an example of this approach.) While it can operate during high river flows, there is in practice a limit to the amount of bed load that can accumulate in the station before it must be removed. This limits the pump window in extended events.
- Siting the pump station on a reverse re-entrant channel, rather than on the main river flow. In this way, the primary flood debris and bed load is directed past the pump chase. This approach works well in braided streams.
- Accepting high pump wear in cases of high sediment concentrations. Axial flow pumps are more tolerant to this approach than centrifugal or mixed-flow pumps, where damage to wear rings can see pump efficiency drop dramatically. Water lubricated bearings in axial flow pumps also work well from this perspective, provided they are fed from a separately filtered source.

In the cases being examined in this study, and for most inland streams across northern Australia, the issue of bed-mobilised sands and gravels is likely to be less of an issue than for the east coast of northern Australia. While regional geology plays a small part in this, the predominant reason is the much higher grades on east coast streams, supporting the transport of larger particle sizes than lower sloped northern Australian streams.

As a very minimum requirement for low design standard axial flow pumps normally used in a typical flood-lifting application, the screening incorporated into the pump inlets would be the only water conditioning. If these become blocked, the normal remedy is to allow the pumps to discharge backwards uncontrolled until the debris is cleared.

At the other end of the scale, some high design standard pumps are designed with telescoping inlets to allow water to always be drawn from near the top of the water surface, avoiding bed load debris.

Most pumps will be somewhere between these extremes.

3 Preliminary cost estimation

For the reasons outlined above, cost estimating for pump stations and rising mains for rural and agricultural applications is notoriously difficult, as situations vary enormously. For a meaningful cost estimate to be possible, the following would be the minimum data required:

- survey of the pump site and rising main
- geotechnical investigation of the pump site and rising main alignment
- a rating curve and flood frequency analysis for the river at that site
- an understanding of the availability and load capacity of any relevant electricity network.

At a pre-feasibility desktop study level, such data are not available, and costs must be estimated by other means. The following has proven useful as a starting point for such preliminary cost estimates.

Just prior to 2000, a study of all SunWater and water board pump stations in northern Queensland was completed to examine whether costs were related to any of the available characteristic data values. For SunWater costs, replacement cost estimates were available as part of discounted optimised replacement cost estimations that were conducted at the time. For state water board pump stations, only those for which recent actual costs were available were included. Results were further culled to exclude those pump stations that did not fit the most common model of types of pumps involved. Most noticeably, this excluded the very large concrete volute pump stations in the Burdekin River. Also, any station with rising mains longer than 100 m was adjusted to exclude the balance of the rising main. This resulted in over 20 data points. The results were mixed, with substantial variation, reflecting more than any other point the variance in design standard referred to above. Nonetheless, a useful correlation between total construction cost and flow in cubic metres per second times total head could be derived. For low design standard pump stations, the costs in dollars in the year 2000 were about $30,000 per cubic metre per second of flow per metre of lift, and for higher design standard pump stations, $45,000 per cubic metre per second of flow per metre of lift. In this instance, low design standard means a simple enclosure in the river. Higher design standard, in most cases, referred to dry well installations, which are mostly a circular concrete well, anchored to the bedrock, and extending to above maximum flood level. The degree of water conditioning provided complicated this simple categorisation.

Converted to December 2023 values using the Australian Bureau of Statistics construction index indicates a present-day value of $60,500 for low design standard and $90,000 for higher design standard installations. As indicated above, such costing functions are only relevant until more detailed site information becomes available. They also do not cover the simpler types of installation normally used for flood-harvesting operations, using axial flow pumps with minimal concrete structures. These would be at values lower than the low design standard number mentioned above.

4 Example design and associated costings

This section focuses on water harvesting applications, although an installation designed to supply a reticulated area, pumping from a small re-regulating storage downstream of a potential dam-site could look very similar, albeit to a higher design standard if it were supplying multiple enterprises.

A Northern Australia Water Resource Assessment technical report on farm-scale dams and costs by Benjamin (2018) presented data for a 4-GL ringtank as one of the options canvassed. For the purposes of this example an area along Flying Fox Creek in the Roper catchment is examined. This was the area targeted for potential irrigation development in the report on the catchment of the Roper River (see Roper River Water Resource Assessment technical report on surface water storage, Petheram et al. (2022)). In that study, water from a potential reservoir at Site 79 is released into Flying Fox Creek and flows over 50 km downstream to a re-regulating weir , and a long rising main to command the area adjacent to and to the south of Flying Fox Creek.

This area also offers the potential for water harvesting operations, and a suitable location for an offstream storage exists at the northern end of the target area. In this example, there would be no re-regulating weir and the optimum location for flood-harvesting pumps would be where the stream channels come together before the heavily braided area on the Flying Fox Creek floodplain.

A potential layout is shown in Figure 4-1, and would include the following features:

- pump site with a rising main some 100 m long
- intake channel at the same level as the top of the storage, some 900 m long
- square ringtank with centre-line side lengths of 1180 m
- crest elevation of intake channel and embankment of EL69.25
- full supply level of EL68.5.

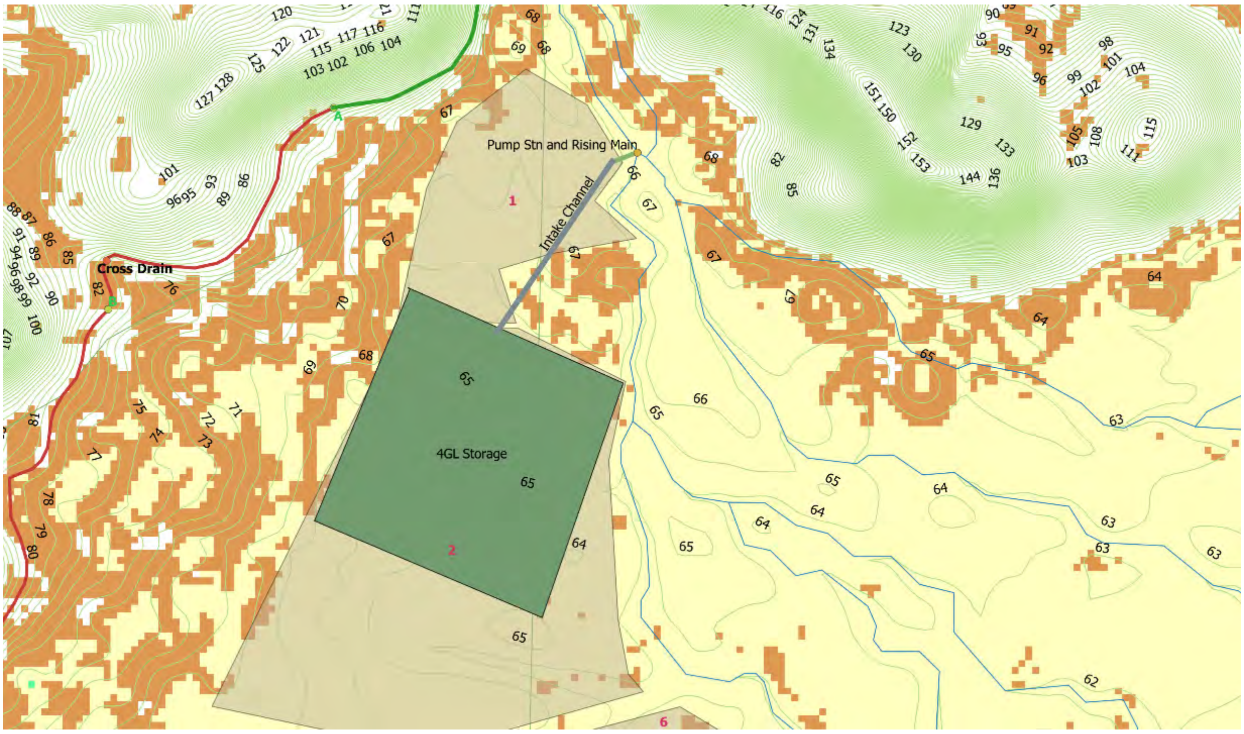

Figure 4-1 Nominal layout of hypothetical flood-harvesting storage and pump station on Flying Fox Creek in the Roper catchment

It should be noted that other options exist, such as a rectangular storage nearer the pump point. However, this will not have the same storage to excavation ratio as the square storage. Hence, this option is used to keep the costing assumptions aligned with the report by Benjamin (2018).

Other characteristics relevant to the costing are:

- pump capacity: 160 ML/day, as per Benjamin (2018) (1.85 m^3/second)
- design lift: 6 m (comprised of 3.5 m static and 2.5 m as inlet, column, bend and outlet losses).

For a one-pump unit design, the appropriate pump is a Model 24 Batescrew axial flow pump, driven by a 200-kW diesel motor through a right-angle drive located on the river bank (Table 4-1). Following the selection of the pump the pump structure and rising main are designed. In the absence of detailed topography or geotechnical information the following assumptions are made:

- The selected pump site is a stable section of the creek, and a suitable slab foundation can be constructed for the pump unit that will not be damaged under expected flood flows.
- The pump will use an angled configuration, with the discharge section of the pump horizontal, but below bank level.
- A motor platform will be constructed above expected flood level to site the diesel motor. Diesel has been assumed due to the remoteness of the location. As noted above, the required motor size is 200 kW.
- The discharge end of the pump column will be assumed to be 6 m long from the bend in galvanised steel pipe, before transitioning to high-density polyethylene (HDPE) for the balance of the 100-m rising main to the intake channel.

- Pump pricing will be based on the following:
  - Inlet will be at EL64.5, reflecting a small pool excavated into the bed. This will give the required submergence for the pumps, although it is appreciated that the permitted starting flow will be at a river stage above this level.
  - The river bank elevation is above EL67, so the pump bend will be assumed to be at EL66.5.
  - Motor level will be above EL68 to give the required flood protection to the diesel motors.
  - The outlet of the HDPE rising main to the inlet channel will have a simple flap gate, to avoid backflow when either pump is not operating.
  - The rising main line will have a branch near the valve to allow air egress on filling, and to allow back flushing with pump stoppage.

Table 4-1 Indicative cost estimate for the above installation

CATEGORY	ITEM	$
Supply items		
	Batescrew 24, angle install, right-angle drive, 200-kW John Deere diesel power pack	$206,000
	Flap valves	$4,000
	Pipe supply DN800 PN6.3 HDPE 94 m	$46,000
	Fuel storage and supply line	$8,000
Earthworks		
	Site preparation	$5,000
	Pump sump	$15,000
	Gravel hardstand area 250 m^2 at $40/m^2	$10,000
Install items	Pump foundations on batter – 1.0 m^3 at $2500/m^3	$2,500
	Motor and pump slab – 4.5 m^3 at $2000/m^3	$9,000
	Pump install and commission	$20,000
	Rising main install ND800PN6.3 – 94 m	$18,000
	Outlet structure, including bypass	$20,000
	Control and monitoring hardware	$15,000
	Total (ex GST)	**$378,500**

Note that this corresponds to $34,000 per cubic metre per second per metre of lift using the metrics discussed above. This as expected is below the low design standard installation number developed in Section 3.

As a comparison, quotes were also obtained for the same style of pump, using a dual pump and dual rising main (Table 4-2). In this instance, the pump selection was a Batescrew 21, coupled to a 95-kW John Deere diesel motor. The major differences between the two layouts are:

- pump duty reduces to about 5.2 m
- rising main reduces to DN630 PN6.3.

Table 4-2 The full estimate for the two-pump case

CATEGORY	ITEM	$
Supply items		
	2 × Batescrew 21, angle install, right-angle drive, 95-kW John Deere diesel power pack	$302,000
	Flap valves	$8,000
	Pipe supply DN630 PN6.3 HDPE 188 m	$52,640
	Fuel storage and supply line	$8,000
Earthworks		
	Site preparation	$5,000
	Pump sump	$15,000
	Gravel hardstand area 300 m^2 at $40/$m^2$	$12,000
Install items	Pump foundations on batter – 2 × 1.0 m^3 at $2500/$m^3$	$5,000
	Motor and pump slab – 2 × 4.5 m^3 at $2000/$m^3$	$9,000
	Pumps install and commission	$30,000
	Rising main install ND630PN6.3 – 188 m	$26,300
	Outlet structure, including bypass	$30,000
	Control and monitoring hardware	$20,000
	Total (ex GST)	**$522,940**

Note this corresponds to $54,000 per cubic metre per second per metre of lift using the above metrics.

While the two-pump options will have advantages in terms of available pump downturn and lower operational costs for fuel (8% less), those advantages are unlikely to justify the additional expenditure. However, it is included to illustrate the sensitivity of total cost to some of the underlying assumptions.

5 Summary remarks

Flood-harvesting pump installations are typically axial flow pumps located on a suitable section of river bank, with minimal surrounding infrastructure.

Rising mains, leading from the pump to the conveyance channel or offstream storage are normally kept as short as possible to limit cost.

Motive power for the pump/s can be electric if distribution networks allow, but is more usually by diesel power pack. Motors need to be above normal flood range.

A preliminary estimate of the installed cost of a pump and rising main and power pack can be gained from a multiple of the duty flow and head, using a value of $30,000 to $40,000 per cubic metre per second per metre of total lift.

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