Title: Integrated Waterways: Understanding Confluences and Synergies in Water, Sewage and Stormwater Management

Glenn Browning

Healthy Land and Water, Brisbane

Healthy Land and Water (HLW) recently reviewed the Stormwater Management Design Objectives (SMDOs) within the State Planning Policy (SPP) in Queensland. This resulted in the publication of the SPP Scientific Report and the Blueprint for Improving Waterway Management in 2020. These Reports found that the SMDOs could be improved by taking a whole of catchment viewpoint rather than just focusing on an active development front. In developing options to address this issue these reports both recommend the reintroduction of Integrated Water Planning (IWP) (also known as Total Water Cycle Management Planning) to empower local governments and regional planners. IWP aims to break down the silos between Water, Sewage, Stormwater and Flooding for the benefit of the economy, community, environment and especially the waterways.

In an effort to help break down silos between various water streams, HLW has created an extension to the Strategic Waterways Tool called Integrated Waterways to enable water managers to understand and find the overlaps and synergies between Water, Sewage and Stormwater. This tool uses a 'RGB' (Red, Green and Blue) colour code to quantify the degree of integration of a city's water cycle. For example, the primary water sources are sewage = red, stormwater = green and water = blue. Integrated projects are highlighted by the emergence of secondary colours (cyan, yellow, and magenta) within the scoring tool and include:

- Pollution risk reduction (e.g. yellow projects)
- Resource conservation and recovery (e.g. magenta projects)
- Cost savings and improved return on investment (e.g. cyan projects)

This is a novel way to undertake systems thinking and can help managers to highlight and zero in on the key areas of confluence between these water sources.

Key words: Integrated Water Planning, Waterways, Risk, Strategy, Systems thinking

Background

Healthy Land and Water (HLW) were commissioned by the Department of Environment and Science (DES) to examine the Stormwater Management Design Objectives (SMDOs) within the State Planning Policy (SPP) in Queensland. This resulted in the publication of the SPP Scientific Report (WbD with Alluvium 2018) and the Blueprint for Improving Waterway Management (WbD 2020). These reports found that the SMDOs could be improved by taking a whole of catchment viewpoint rather than just focusing on an active development front. In developing options to address this issue, these reports both recommend the reintroduction of Integrated Water Planning (IWP) (also known as Total Water Cycle Management Planning) to empower local governments and regional planners. IWP aims to break down the silos between Water, Sewage, Stormwater and Flooding for the benefit of the economy, community, environment and especially the waterways.

In 2021, HLW continued the investigation into this topic and drafted the Integrated Water Planning Discussion Paper (WbD 2021). The discussion paper included an extensive literature review, interviews with councils, consultants, utilities and institutions, and proposals for improving the uptake of Integrated Water Planning across Queensland.

The Author has used this foundational research into IWP and combined it with earlier work which included strategic planning for waterways using colour coding (Browning 2019) to develop a new model called Integrated Waterways to assist water cycle managers to view our water systems in a new light.

Understanding the Problem: When is Integration Appropriate?

Integrated Water Planning is not new, there have been many investigations over the last decade throughout Queensland. The Cooperative Research Centre for Water Sensitive Cities has been working on this topic since its inception (CRCWSC 2020) and many other organisations have contributed to this field of practice. Observations from recent interviews suggest that for small towns IWP can be an onerous burden, but for larger councils it is perhaps the only way to grapple with complex water systems (WbD 2021).

The purpose of this paper is to help waterway managers understand the system dynamics of the urban water cycle. This paper 1) describes why water cycle silos are occurring and how we might attempt to break down the silos, and 2) outlines a tool (*Integrated Waterways*) that can be used to help water cycle managers understand the system dynamics and identify suitable water integration projects. The proposed methodology and metrics can help to identify when an Integrated Water Planning approach may be most beneficial and/ or to help select the best performing project out of a number of different IWP projects

Primary Objectives of Water Services

Traditionally, water services have been divided into three separate disciplines to meet three distinct primary objectives as follows (WSAA 2020):

- Water management – provide drinking water,
- Stormwater management – prevent flood damage and pollution,
- Wastewater management – prevent pollution and disease.

It is entirely possible for each water stream to operate independently, especially for small townships or simple systems. While there is no interaction between the water sectors, this represents a primary state. Figure 1 shows each business operating model at a basic level with key parameters that will affect operations. While there are no stressors on any of these factors, the businesses can operate separately. When any one of the parameters changes or is restricted in any way, a driver is created to move towards Integrated Water Planning.

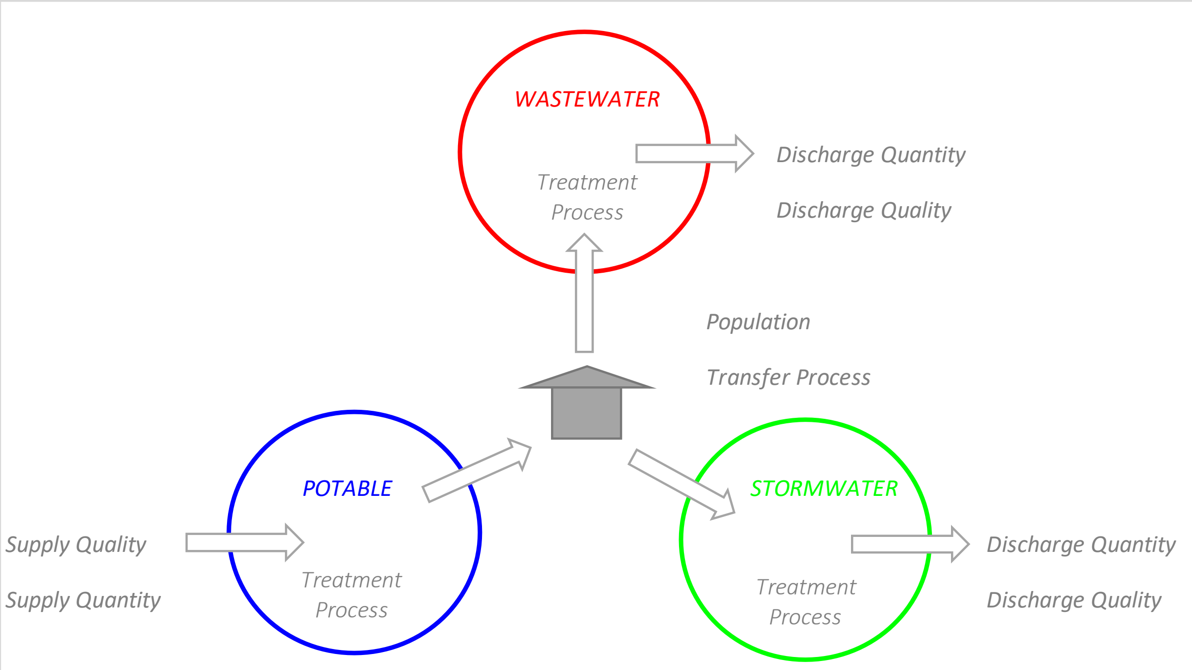

Figure 1 - Simple business operating model and parameters affecting operation.

The Benefits of Water Cycle Integration

Moving from the basic operating model to a more integrated operating model can have many benefits. As documented below (WbD 2010), IWP can:

- Supply sufficient water to support a comfortable, sustainable and prosperous lifestyle, while meeting the needs of urban, industrial and rural growth, and the environment.
- Achieve targeted reductions in water consumption to decrease pressure on water supplies and the environment.
- Manage risks in drinking water catchments to achieve acceptable water quality.
- Provide necessary flood immunity for infrastructure and buildings, and resilience to potential climate change flooding, while seeking to maintain the natural flow regime.
- Supply and use rural water in an efficient and sustainable way.

Furthermore, IWP is particularly relevant for waterway management as it can deliver multiple outcomes such as:

- Protect and enhance the ecological health, environmental values and water quality of surface and groundwater, including waterways, wetlands, estuaries.
- Help us understand the catchment's water and nutrient balance and understand the waterway's thresholds and limits,
- Identify and mitigate risk hotspots and magnify our impact,
- Identify new opportunities and methodologies to limit pollution,
- Find opportunities to enhance livability through increased water availability and blue green infrastructure,

- Find efficiencies and synergies in our water systems via resource conservation and resource recovery,
- Defer expensive infrastructure upgrades such as desalination plants with cost savings reinvested in waterways,

Drivers for Integrated Water Planning

As the population increases and cities get larger, the capacity of our water infrastructure needs to be increased to meet the demand. This often puts stress on the natural environment and its ability to supply fresh water or assimilate pollution starts to become critical. Things like water shortages and fish kills will start to prompt regulations and pollution controls and this often becomes a catalyst for the integration of the water cycle. Opportunities to improve processes (e.g. cheaper, more reliable, more efficient) are another catalyst for integrating the water cycle. Table 1 outlines common drivers for water cycle integration.

Table 1 - Key drivers for water cycle integration

Key Drivers for IWP	Examples
'Quality' stressors	Water: raw water supply quality Stormwater: receiving environment water quality & discharge regulations Sewage: receiving environment water quality & discharge regulations
'Quantity' stressors	Water: supply reliability Stormwater: flood volumes and frequency Sewage: discharge volume and frequency
Treatment processes	Risks: leakage, spills, overflows, storage Cost: energy, maintenance, resourcing Treatment inputs (e.g. cost, availability or impacts of treatment chemicals), Treatment byproducts (e.g. cost and impact of disposal of sludge)
Transfer (reticulation) processes	Risks: leakage, spills, overflows, storage Cost: energy, maintenance, resourcing Infrastructure: pipes, pumps, valves, pits, manholes
Population and other stressors	Population increases Service expectations Climate variability and change Sustainability drivers

The above table can be developed intoa checklist to identify when a basic system may need to integrate to a more advanced system. Fundamentally a move to IWP can be justified when there are improved economic, social and environmental benefits and / or reduced economic, social and environmental costs compared to the status quo.

It must be noted that the integration of the water cycle represents a more complex state, and it takes much more cooperation, collaboration, and coordination to achieve successful outcomes. For this reason, it may not be appropriate to implement IWP in all situations especially at smaller scales where the additional planning and modelling may be too onerous . Previous legislation in Queensland set the minimum population threshold for a council to enact IWP at 10,000 for this very reason.

How Can We Integrate Water Silos?

It should be mentioned that even in a very basic system, water sectors are still interlinked and in general, managers of one part of the water sector will be mindful of other water sector objectives. For example, water treatment plant (WTP) sludge could be dumped economically in a river to the detriment of the water quality of the river. However, WTP operators are mindful of the primary goal of other sectors (i.e waterway health) so this requirement to dispose of treatment byproducts carefully becomes a secondary goal for water service providers and dumping of WTP sludge does not usually occur.

Secondary Objectives of Water Services

Traditionally, the secondary goal for a water sector may only extend as far as to avoid hindering other sectors in achieving their primary objectives (as stated in the above example). However, with Integrated Water Planning, each water sector can take an active role in meeting the primary objectives of the other sectors.

Identifying Areas of Confluence

There are many areas where water, sewer, and stormwater overlap. It is these precise areas of overlap that are important for IWP and should be the focus of waterway managers. Table 2 provides a list of potential infrastructure solutions that can address these areas of confluence.

Table 2 – Key areas of confluence

Water/Wastewater	Water/Stormwater	Stormwater/Wastewater
• Greywater reuse • Blackwater reuse • Purified Recycled Water • Managing septic tanks / overflows in drinking water catchment • Water conservation	• Rainwater tanks • Stormwater harvesting • Passive Irrigation • Aquifer Storage and Recovery • Water supply catchment restoration (e.g. WSUD / revegetation)	• Sealed sewer systems • No stormwater connections to sewer • No sewage overflows to stormwater or waterway • SW to WW offsets • WW to SW offsets

Note: W = Water, SW = Stormwater, WW = Wastewater

Integrated Waterways: A Tool

To assist water managers to deconstruct silos within the water industry, HLW has created an extension to the Strategic Waterways Tool called *Integrated Waterways*. The tool helps users understand and find the confluences and synergies between Water, Sewage and Stormwater. The excel based tool includes a questionnaire that will allow waterway managers to evaluate to what degree a given infrastructure project can deliver on the objectives of multiple water sectors. It can also be used to help compare potential projects.

This tool uses a 'RGB' (Red, Green and Blue) colour code to quantify the 'degree of integration' of a city's water cycle. The primary water sources are sewage = red, stormwater = green and water = blue. Integrated projects involving the confluence of more than one water sector are highlighted by the emergence of secondary colours (cyan, yellow, and magenta) within the tool. Since sewage is red and water is blue, any project that achieved the goals of both water and sewage would a vivid magenta colour (i.e the combination of Red and Blue).

This is a novel way to undertake systems thinking and can help managers to highlight and zero in on the key areas of confluence between these water sources. It is noted that while the RGB colour system is also used in Strategic Waterways, the two tools work in different ways. Strategic Waterways is a 'competitive model' and can be used when resources are limited. Integrated Waterways is a 'cooperative model' and can be used when resources can be shared. It is envisaged that as these tools are further refined, new ways of visualizing and solving complex three-dimensional problems will emerge.

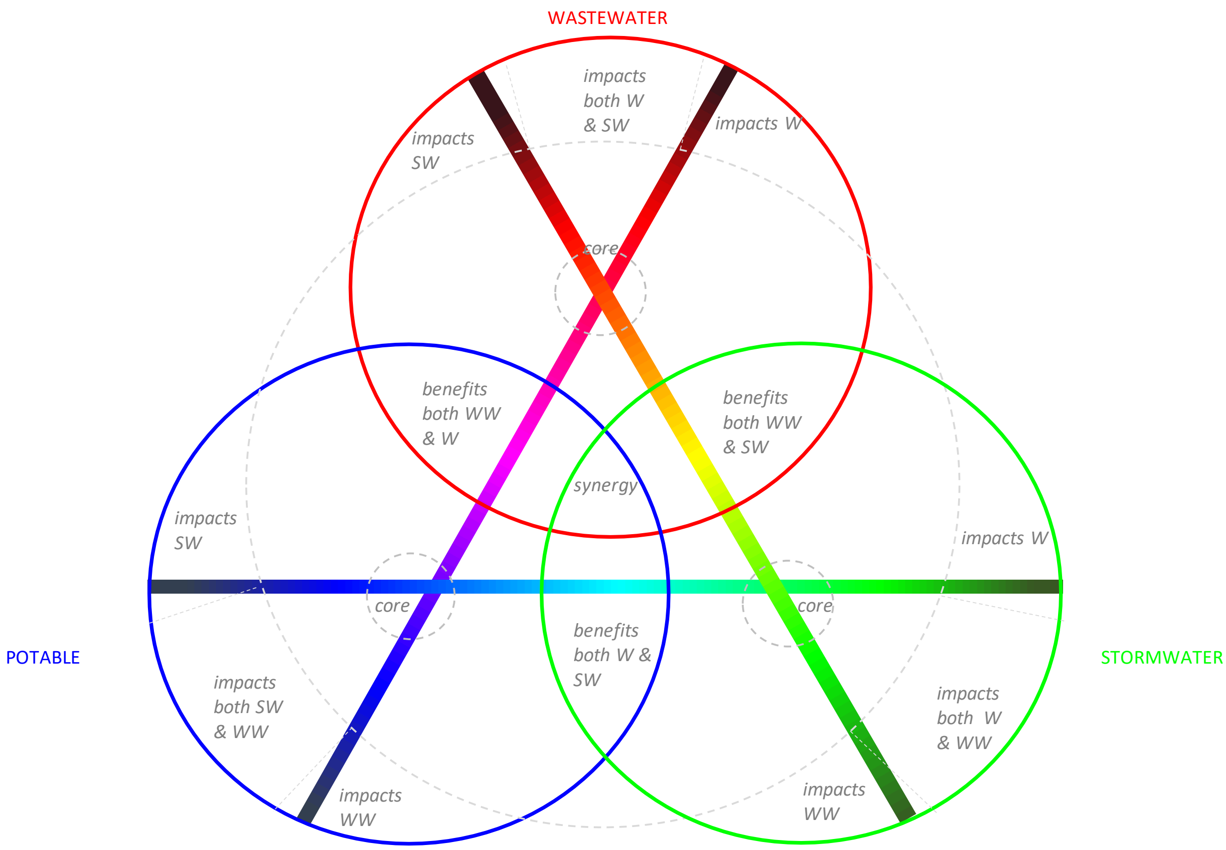

Figure 2 - Using RGB colours to represent water integration

Visually Identifying Key Areas of the Water Cycle to be Integrated

A model of an integrated water cycle is represented visually in Figure 2. The diagram illustrates: Core activities (appropriate to each water sector), Synergies (where goals overlap and align), Detriments (where an activity is to the detriment of other water sectors).

Figure 3 also shows how RGB colours would vary depending on the degree of integration between various primary water sectors. Where the Venn diagram overlaps and there are synergies, secondary colours emerge. Where there are significant detriments occurring to other water sectors then this can also impact on colour hue and the scoring system in the tool results in a darkening of the primary colour.

Integrated projects are highlighted by the emergence of secondary colours (cyan, yellow, and magenta) as tabulated in Table 3. Typically:

- magenta projects involve resource conservation and recovery,
- cyan projects involve capitalizing on available water and improving return on investment,
- yellow projects involve pollution risk reduction.

Table 3 – Example Integrated Water Projects

Magenta Projects **Blue + Red**	**Cyan Projects** **Blue + Green**	**Yellow Projects** **Red + Green**
Water and Wastewater ***Resource Recovery***	***Water and Stormwater*** ***Capitalise on Opportunity***	***Wastewater and Stormwater*** ***Mitigate Risk***
Greywater reuse ✓ WW quantity ✓ W quantity	Rainwater tanks ✓ SW quantity & quality ✓ W quantity	Sealed sewer systems ✓ SW quality
Blackwater reuse ✓ WW quantity ✓ W quantity	Stormwater harvesting ✓ SW quantity & quality ✓ W quantity	No SW to WW cross-connections ✓ *WW quantity*
Purified Recycled Water ✓ WW quantity ✓ W quantity	Passive Irrigation ✓ SW quantity & quality ✓ W quantity	No WW overflows to SW ✓ *SW quality*
Managing septic tanks in drinking water catchment ✓ WW quality ✓ W quality	Aquifer Storage and Recovery ✓ SW quantity & quality ✓ W quantity	SW to WW offsets ✓ *WW quality*
Water conservation ✓ WW quantity ✓ W quantity	Catchment Restoration ✓ SW quality ✓ W quality	WW to SW offsets ✓ *SW quality*

1. W = Water, WW = Wastewater, SW = Stormwater
2. SW quality is assumed to also equate to waterway quality

Quantifying the Degree of Integration

The Integrated Waterways tool allows users to quantify and visualize 'degree of integration' across the water cycle. This can then be represented with a RGB colour code and displayed graphically.

Key steps for the tool are as follows:

1. The tool comprises of an audit of key drivers (Table 1) for each water sector establishing the need for integration,
2. Key water cycle infrastructure is mapped in the Venn diagram noting synergies, detriments and core services (Figure 2),
3. Proposed integrated water solutions (Table 3) are assessed against the ability to deliver positive outcomes each of the five key drivers (Table 1)
4. The tool will then calculate the 'degree of integration' and assign an RGB code.
5. A suite of solutions can then be evaluated with the chart below (Figure 3) indicating the degree of integration of water systems and noting deficiencies.
6. The tool can be used to compare potential projects of if used in multiple cities, the tool can be used as a benchmark to compare the water cycle integration for various cities.

Although the Integrated Waterways tool is still in the process of being refined, it is anticipated that the tool can also be used in other applications where there is a need to bring together three interrelated parts. for example: Environment, Community and Economy. or Time, Quality and Budget etc.

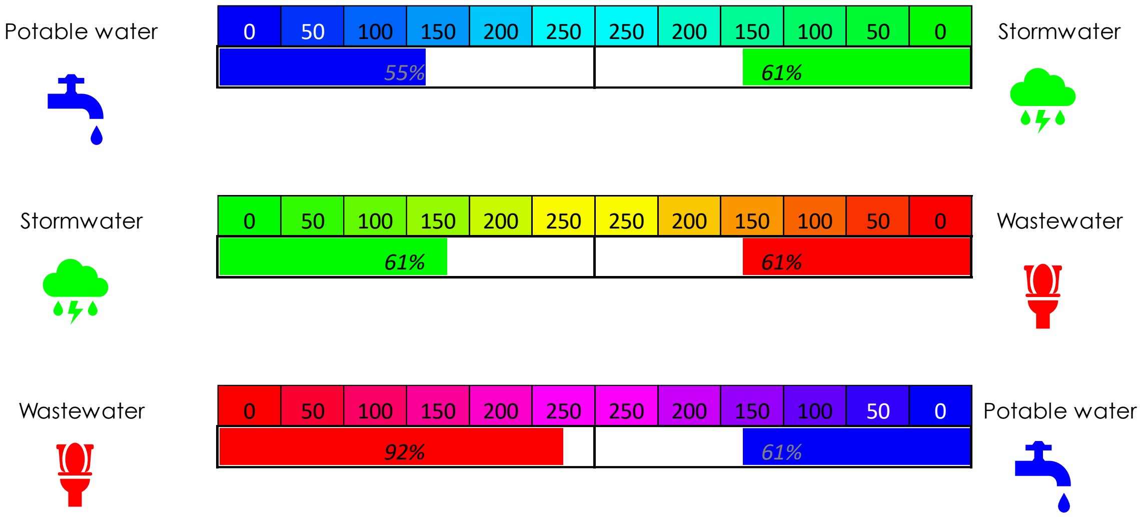

Figure 3 – Integrated Water Network using RGB colours

Discussion and Conclusions

This paper has outlined key drivers for integration for the water sector as well as the benefits that can be delivered to water systems and the waterway.

Due to the additional planning costs required to transition, it can often be unclear if the move to IWP will be of merit, especially for smaller towns. To assist waterway managers with these queries, HLW created Integrated Waterways, a mathematical and visual tool that can calculate and visually represent synergy or the degree of integration. Local governments can use this tool to assess their water systems and determine to what extent moving to an integrated water cycle will solve key issues.

As climate change and population increase add stress to our water systems, water managers will need to look outside their typical sphere of operation to solve complex problems. Water systems of the future will need to be capable of delivering more than one primary function and integration will become more and more necessary.

Acknowledgements

- Thanks to Maria Lucia Neme Gaviola who was involved in the initial brainstorming that laid the foundations for this tool. Please read her thesis for discussion on bringing together Environment, Economy and Community.
  Neme L, (2020) "Planning for Sustainable Mining Regions" University of Queensland
- Thanks to Jack Coates-Marnane for kindly reviewing this paper.
- Thanks to my colleagues at HLW for creating a supportive environment and to the broader stormwater industry for the positive feedback and encouragement.
- Thanks to the Department of Environment and Science for their continuing support for the Water by Design program.

References

1. *Weber, T et al (2018), "Stormwater Management Design Objectives" Alluvium* *https://waterbydesign.com.au/download/spp-review-scientific-review*
2. *Water by Design (2020) "Blueprint for Improving Waterway Management" Healthy Land and Water* *https://waterbydesign.com.au/download/spp-review-blueprint-for-improving-waterway-management*
3. *Malekpour, S., Tawfik, S., Chesterfield, C. (2020). Designing cross-sectoral collaborations for integrated urban and water planning. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities.*
4. *Tawfik, S. and Chesterfield, C. (2020). Facilitating water sensitive urban development through planning integration — A discussion paper. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities.*
5. *Water by Design (2021), "Integrated Water Planning Discussion Paper" Healthy Land and Water (yet to be published)*
6. *Water by Design (2010) "Total Water Cycle Management Planning Guideline" Healthy Land and Water* *https://waterbydesign.com.au/download/total-water-cycle-management-planning*
7. *WSAA (2020) "Transitioning the water industry with the circular economy" Water Services Association of Australia and UTS Institute for Sustainable Futures* *https://www.wsaa.asn.au/publication/transitioning-water industry-circular-economy*
8. *Browning, G.D. (2019), "Strategic Waterways" Healthy Land and Water* *https://waterbydesign.com.au/news/strategic-waterways*