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Sewage: from liability to asset, the Shoalhaven REMS project. *A review after twenty years of initial operation* Australia's largest regional wastewater recycling scheme: greatly reducing effluent discharge to sensitive waterways and increasing dairy farm productivity

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Abstract

An overview of the **RE**claimed Water **M**anagement **S**cheme (**REMS**), Stages 1A & 1B undertaken by Shoalhaven Water, the water utility of Shoalhaven City Council, NSW, Australia, after its first twenty years of operation. REMS is one of the largest recycled effluent projects undertaken by a local government in Australia. REMS utilises tertiary treated reclaimed sewage water from the urban centres and utilises it, in lieu of potable water, for agricultural and sports field irrigation, while diverting discharge away from sensitive waterways. The REMS project was initiated to address three primary issues: public outcry over sewage discharge into sensitive Bay/River/Ocean environments including Jervis Bay and the Shoalhaven River; assisting the dairy industry though providing resistance to drought; upgrading the sewerage system to enable development and address the demands of a greatly increased population. This paper places the scheme in the context of an integrated water utility and local government body, engaging stakeholders in extensive consultation, and embarking on a large project designed to have significant environmental and economic outcomes, culminating in an integrated multi-plant capture, treatment and distribution system. The project is focussed upon agricultural use of recycled water that has wide public support, and benefits to both the dairy farmers and oyster farmers of the region. The paper examines REMS' success, its future expanded capabilities, and its application as a scalable model elsewhere.

Key words: biosolids, consultation, dairy/agriculture, distribution, oysters/aquaculture, reclaimed water

Highlights

- Shifting the perception of treated effluent from liability to asset.
- A local government body engaging, acting and delivering environmental and economic outcomes.
- Significant increases in agricultural production due to guaranteed water supply, the effective utilisation of biosolids for soil conditioning.
- Future distribution opportunities via shared easements, infrastructure and rail.
- Addressing public outcry over the environmental hazard of treated effluent discharge into waterways.

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Graphical Abstract

THE SHOALHAVEN WATER REMS (RECLAIMED WATER MANAGEMENT SCHEME)

Shoalhaven Local Government Area, NSW, Australia.

Australia's largest regional wastewater recycling scheme, which has greatly reduced effluent discharge to sensitive waterways and helped increase dairy farm productivity.

An overview of this comparatively simple project after 20 years of initial operation, REMS Stages 1A +1B.

INTRODUCTION

Located 150 kilometres south of Sydney, and a similar distance east of Canberra, in a region of high environmental quality, the Shoalhaven REMS (**RE**claimed water **M**anagement **S**cheme) project, one of Australia's largest regional wastewater recycling undertakings, has greatly reduced effluent discharge to sensitive waterways, increased dairy farm productivity and enabled responsible, sustainable, future development (Figure 1).

An initiative of Shoalhaven Water, the water utility of Shoalhaven Council located on the south coast of NSW Australia, the REMS scheme is designed to beneficially re-use reclaimed water (treated sewage water) in agricultural (principally dairy), municipal and other uses, in order to replace the use of potable water for these purposes, and to protect sensitive marine environments through greatly reduced volume and highly increased quality of outfall.

The scheme was initiated in response to concerns over significant population growth in the region during the 1980s and the need to identify an appropriate sewerage scheme to avoid environmental pollution to sensitive waterways (Gould *et al.* 2003).

The objectives of the scheme were to:

- Reduce treated sewage discharges to sensitive bay/river/ocean environments and in so doing protect important marine environments including Jervis Bay Marine park and oyster farms
- Drought proof local agriculture, specifically the dairy industry
- Establish an integrated sewage treatment regime capable of producing high quality reclaimed water in appropriate volumes, to address a significantly increased population and facilitate future growth.

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Figure 1 | The REMS project; Nowra, Shoalhaven Local Government Area, New South Wales, Australia. 34.53° Sth/150.36° East. *Source:* Google Earth + Author graphics.

This was achieved in two initial stages by:

- Engaging end users, establishing protocols, procedures and obligations and participating in extensive public consultation
- Exploring financing options that involved ratepayers, three levels of government and end users
- Cost benefit analysis
- Identifying the range of end uses
- Creating a collection and distribution network
- Upgrading existing sewage treatment plants and supplementing these with additional plants and infrastructure
- Optimising the quality and volume in the generation of reclaimed water suitable for beneficial re-use purposes.

The project was conceived in the 1990s and initiated at the turn of the century, followed by a 20-year project delivery period, culminating in the completion of Stage 1B in January 2020.

The project is noteworthy for a number of important reasons:

- It was initiated by public environmental concerns
- It needed to foster public engagement and convert it to ratepayer engagement, and it created a visible productive continuing dialogue
- It needed to engage an initially sceptical, already restructuring, dairy industry

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- It needed to educate the public and dairy farmers about the use of reclaimed water generated by urban centres for agricultural and civic purposes
- The marine environment included a significant oyster industry, sensitive to water quality
- Three tiers of government, Local State and Federal, were needed to co-ordinate for funding and approvals
- It could be implemented progressively using relatively simple technology.

There was a need to significantly improve the prevailing sewage treatment and disposal status quo to enable future development, in a Local Government Area (LGA) that has seen its resident population increase more than three-fold since 1970.

The immediate REMS area is of a reasonable scale, having an urban population of 60,000 people that triples in summer, a relatively complex urban environment that includes industry defence, services, health, education and cultural infrastructure.

The area is a focus of both domestic and international tourism, showcasing high quality marine, river and wilderness environments including notable indigenous and European heritage, with mixed agriculture and aquaculture.

The REMS dairy irrigation area is located on the Shoalhaven River/Crookhaven River flood plain. The area is characterised by a temperate climate with good general rainfall. The area has been prone to significant drought events and significant flood events; the flood events are generally freshwater flooding from upstream flow; however, there has also been periodic salt water flooding. There is a range of soil types across the flood plain/river delta area.

The century-old dairy industry in the region had traditionally not used irrigation, generally relying on rainfall; however, there have been a number of droughts that took it to the edge. The dairy industry was also in the throes of a major re-structure and review.

It is worth noting that the emphasis on the utilisation of reclaimed treated effluent water in the REMS scheme was for agricultural and civic purposes, this was not a project to produce potable water (Gould *et al.* 2003).

This was an important aspect to the public enthusiasm for the scheme.

REMS has a target utilisation rate of 80% of recycled effluent. Non-utilised recycled effluent is discharged to the ocean at Penguin Head. In the event of emergency or system overflow, some discharge will occur into Jervis Bay at Plantation Point and into the Shoalhaven River at Terrara.

It cannot be emphasised enough that the success of the implementation of the REMS was highly dependent upon the transparency of the consultation process, the advocacy of the utility management, the co-operation of dairy farmer 'pioneers', and the successful co-operation of all levels of government (Mooney & Stenekes 2008).

Early 2020, following the completion of REMS stage 1B, saw the end of a prolonged multi-year drought event, that included widespread potable water use restrictions across the region; devastating summer bushfires flanked the REMS area and ravaged many areas of the Shoalhaven LGA. The fires were followed by a substantial flood event that carried with it the huge volume of detritus left by the fires. Then came Covid19…

This is an appropriate time to reflect on the success and resilience of the scheme.

WHAT PROMPTED THE CREATION OF REMS?

Put very simply, there were three fundamental initiating factors that started the investigation that led to REMS:

- Public outcry over the discharge of effluent into the ocean/river system, particularly into the popular and sensitive environment of Jervis Bay, and the Shoalhaven River, with its associated oyster farms

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- A struggling dairy industry badly affected by a lack of confidence due to needing to address 'structural change', technological change, pricing chaos and the threat of drought; the dairy industry being a very important part of local agriculture
- Constraints on development capacity within the LGA imposed by the State government, identifying the limitations of the existing sewerage treatment system and the stress placed on it by a greatly increased population (Gould *et al.* 2003).

WHO IS REMS OPERATED BY?

Shoalhaven Water is the responsible water utility, providing water treatment and supply plus the treatment and management of sewage; Shoalhaven Water is owned by Shoalhaven City Council.

As well as the six WwTPs in the REMS network, Shoalhaven Water operates an additional seven WwTPs of varying scales within the LGA, all but one of which contribute to either reclaimed water re-use or capture and use of biosolids, or both (Shoalhaven Water Reclamation Annual Report 2019/20).

The scheme has been funded by a combination of Local government, State government, and Federal government sources.

BACKGROUND

The initial solution, in the early 1980s, for the Jervis Bay discharge had been to create a new ocean discharge at Governer's Head to the south of Jervis Bay.

However, by 1989 ocean outfall proposals were causing public outrage, and the NSW State government determined that no further ocean outfalls would be approved unless appropriate consideration had been given to 'alternative reclaimed water management options'.

With the cooperation of a Community Liaison Group (CLG), comprising elected members of all levels of government, representatives of relevant government agencies, environmental groups and the community, and following an appraisal of a variety of options, three main options were prepared for public review, being:

- Ocean outfalls at three alternative locations (including Governer's Head)
- A land based re-use irrigation option based on forestry
- River release via constructed wetlands with local re-use.

What followed was a long and complex conflict resolution, liaison and education process.

The net result was that the public expressed a strong preference for a land irrigation-based option and indicated a willingness to pay more in sewerage rates to achieved this.

The combination of exploring alternatives to forestry (the original option) for irrigation expansion of the area under consideration beyond the St Georges Basin Jervis Bay area, saw the dairy industry emerge as the appropriate opportunity (Gould *et al.* 2003).

Following extensive public and stakeholder consultation various options were examined and refined.

A two stage plan was devised: Stage 1A would address the Jervis Bay water quality by creating a linked system of four wastewater treatment plants, a holding dam and piped distribution network producing high quality tertiary treated effluent for irrigation of dairy pasture. Stage 1B involved a major upgrade and linking of the two largest wastewater treatment plants at Nowra and Bombaderry, greatly reducing discharge into the Shoalhaven River, benefiting the oyster industry (SRO Oct 2012), and integrating this system with the Stage 1A infrastructure.

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Planning proceeded and funding was procured via local state and federal governments. Stage 1A was commissioned in 2002 during the period of the Millennium Drought; Stage 1B construction was completed in December 2019 during the most recent drought period.

In its implementation, the final version of Stage 1B also included the upgrade of the Stage 1A treatment facilities to meet the Australian Guidelines for Water Recycling (AGWR) which had been introduced more than 4 years after the completion of Stage 1A (McGill *et al.* 2014).

PHYSICAL CONTEXT

The Shoalhaven LGA, bounded by the Great Dividing Range escarpment to the west, and the Pacific Ocean to the east, it is around 150km north/south and 50km east/west, consisting of a wide variety of townships. It has a population of 100,000 people, which triples in the December/January summer holiday period, approximately 60% of the population is in the Northern Shoalhaven Region, including 'Nowra' environs and Jervis Bay (Figure 2).

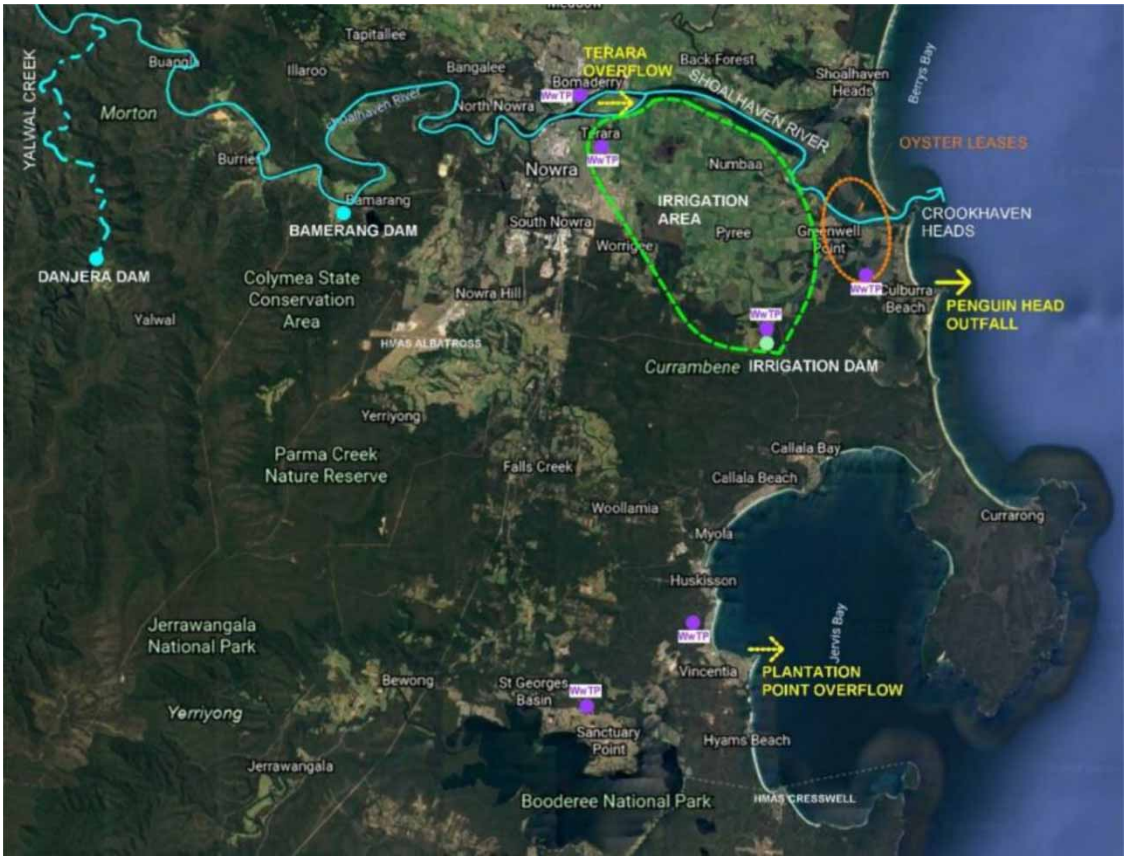

Figure 2 | The REMS Region around Nowra, from Jervis Bay to the Shoalhaven River. *Source:* Google Earth + Author.

Nowra, on the Shoalhaven River, in the northern Shoalhaven region, is the main town and centre for local government for Shoalhaven City Council. Nowra township sits across the Shoalhaven River from a smaller township, Bombaderry, and for the purposes of this article we can consider Bombaderry +Nowra +North Nowra +South Nowra a as a single entity, 'Nowra'.

The region has a temperate climate and generally good rainfall. The region supports general agriculture, including cropping, turf, viticulture, sheep, equine, cattle and a significant 'signature' dairy industry; fishing and a significant 'signature' oyster industry; manufacturing and industry including major ethanol production; a dual naval presence of dock and training facilities at HMAS Cresswell

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on Jervis Bay, as well as the Naval Airwing at HMAS Albatross at Nowra Hill that includes a significant aviation technology park.

It is a region of both Indigenous heritage and European heritage importance.

Tourism, embracing coast, bay, river, agricultural and National Park and other 'wild' environments is a significant part of the regional economy; much of the tourism appeal relates to a 'clean and green' image, complemented by a spectacular coastline, large river basins and a dramatic hinterland.

Over 60% of the LGA remains naturally vegetated (ShoCounc.CR 2016/17).

With a hospital and tertiary education facilities, Nowra is located on the M1 motorway from Sydney and is also linked to Sydney by rail.

The Shoalhaven River is a major river within NSW; Nowra, almost 20km upstream from the coast, is located at the transition point from 'river' to 'river delta', the river is saline and tidal at this point. The Shoalhaven rises west of Burrier to Tallowa Dam; the river flows east to the ocean discharging at Crookhaven Heads 2km east of Greenwell Point. The Shoalhaven River and Crookhaven River (a much smaller river) are joined via Berry's Canal at Greenwell Point, this part of the delta has significant oyster farming infrastructure within the river system.

Nowra draws its potable water supply approximately 20km further upstream on the Shoalhaven River at Burrier, at which point the water is effectively fresh; it is captured in a holding dam at Barawang and processed at the adjacent potable water treatment plant for distribution. This supply is supplemented by an additional dam, Danjera Dam, which releases water into Yalwal Creek that flows into the Shoalhaven River above Burrier. Upon application, in times of drought, supplementary water may be released further upstream from Tallowa Dam, a Water NSW asset, and managed through the Greater Metropolitan Water Sharing Plan.

The area served by REMS is located to the South East of Nowra/Bombaderry from St Georges Basin via Jervis Bay, Coonemia, the Crookhaven River, Pyree and Terrara and flanked by the Shoalhaven River. This area encompasses a high concentration of the population as well as the heart of the regionally important signature dairy and oyster industries.

The REMS dairy irrigation area is located to the east of Nowra on the southern side of the Shoalhaven/Crookhaven river delta within the floodplain. Dairying has been undertaken in this region for over a century.

The Shoalhaven River is tidal and saline in this vicinity and cannot be used directly for irrigation. A substantial oyster industry occupies the Shoalhaven/Crookhaven delta around Greenwell Point, and has done so since the late 1800s (SRO 2012) (Figure 3).

Figure 3 | The Shoalhaven River and Crookhaven River merge at Greenwell Pt. Oyster leases, commercial/recreational fishing and recreational water sports adjacent to the dairying areas of REMS immediately to the West. *Source:* Drone photography by Tom Killingback.

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It is this combination of population, aquaculture and agriculture in close proximity that defines the character and opportunity of the REMS project.

THE OBJECTIVES OF REMS

The intention of the REMS scheme was to:

- Create an integrated effluent capture treatment and distribution network
- Improve the quality of treated effluent
- Reduce the effluent discharge to ocean, bay and river
- Optimise the re-use of treated effluent for agricultural and field irrigation
- Utilise products of the treatment process such as biosolids.

REMS is short for:
The Northern Shoalhaven **RE**claimed Water **M**anagement **S**cheme.

STRATEGY TO MOVE FORWARD

It was clear from the outset that the broader public needed to be engaged in the process; the public needed to understand the whole picture, they needed to understand the options available, and they needed to support the chosen path of the project in order for it to move forward. This was a long-term exercise.

In engaging the public, there were two quite different hurdles that needed to be overcome. The first was that as ratepayers, they now had to commit to the necessity to increased sewerage charges in order to facilitate seed funding for the project. The second was that the public needed to become enthusiastic about the widescale re-use of treated effluent as a substitute for potable water use in agricultural and recreational field use.

For the scheme to be successful, the end users had to be identified and engaged. Golf courses and sports fields were comparatively easy to sign up, as there were plenty of precedents.

The dairy farmers, however, presented a different challenge: this was going to significantly alter the way that they did things; this was going to require significant mutual financial investment; this was dairy, and there were health fears associated with the quality of the treated effluent, and there were concerns about the longer term effect on the soil; there were financial concerns about the short and long term cost of the resource, and there was a natural scepticism about the timeframe and commitment to delivery by Shoalhaven Water (Gould *et al.* 2003).

At the time of this initial engagement, the effects of drought were ever present, within the dairy industry the structure of selling the milk was fundamentally changing, the price of milk was unstable and the market format was in the process of enormous change.

Dairy in this region had no history of irrigation, so this was also a different way of farming with new investment requirements in irrigation infrastructure.

In this region, dairy cows are generally pasture fed with some supplementary maize feed provided by on-farm cropping.

Strong advocacy, engagement, transparency and trust were provided via the Shoalhaven Water management and council; the continuing enthusiasm and advocacy of key dairy farmer representatives; and the support of the NSW State minister with portfolio responsibility for both agriculture and water resources, proved to be a powerful combination. Enabling the project to move forward (Mooney & Stenekes 2008).

Eventually, a core group of farmers committed in principle to participating in the scheme, sufficient to underscore the viability of the scheme.

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This was to be one of the most significant undertakings by a regional water utility in the country: there were many factors riding on its success, including a burgeoning tourism sector that was keen to market the 'clean and green' credentials of the region, which was to evolve into the Shoalhaven 'Unspoilt' tag line.

The scope of the system needed to be outlined and what was to be a 20-year plan confirmed.

THE OBJECTIVE OF SHOALHAVEN WATER IN PRINCIPLE

To create a viable integrated wastewater processing system that produced high quality tertiary treated 'agricultural grade' water to be used for agricultural and civic purposes in lieu of potable water.

To eliminate, for other than in emergency events, the discharge of effluent into either Jervis Bay (now a marine park) or the Shoalhaven River (and its oyster industry).

To reduce the volume and increase the treatment level of treated effluent discharged via ocean outfall.

To investigate uses for treatment byproducts including biosolids from sludge and generated gas.

THE AGREEMENT WITH FARMERS IN PRINCIPLE

Shoalhaven Water would create infrastructure and a network of supply pipework that would terminate at a small buffer dam on each participating dairy farm property.

The water was to be supplied free for an 'introductory' period of 15 years, this arrangement was to be reviewed at that time.

Each individual farmer would need to provide their own irrigation equipment and they needed to commit to this to receive the water (Figure 4).

Figure 4 | Irrigation equipment on REMS-irrigated pasture for dairy feed. *Source:* Author.

Some grant funding was made available as an incentive to 'early adopters'.

The water was originally intended for irrigation only.

HEALTH CONCERNS

Both the dairy industry and oyster industry are very sensitive to health threats to their viability, each are highly regulated and have strict reporting criteria.

Oysters are the 'canary in the mine' for the health of the river, and the industry has rigid protocols for testing and shutting down procedures (SRO Oct 2012).

Dairy farms are the subject of vet testing, milk quality testing and soil testing regimes designed to flag any threat to the health of the herd or the quality of the milk.

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The supplied treated water is itself is subject to constant testing to ensure that the relevant standards are being met (McGill *et al.* 2014).

THE PHYSICAL PLAN

Having reviewed options and examined precedents, an achievable physical plan was identified as a 20-year deliverable, subject to receipt of funding: REMS Stage 1, broken into two distinct substages, 1A and 1B (Figure 5).

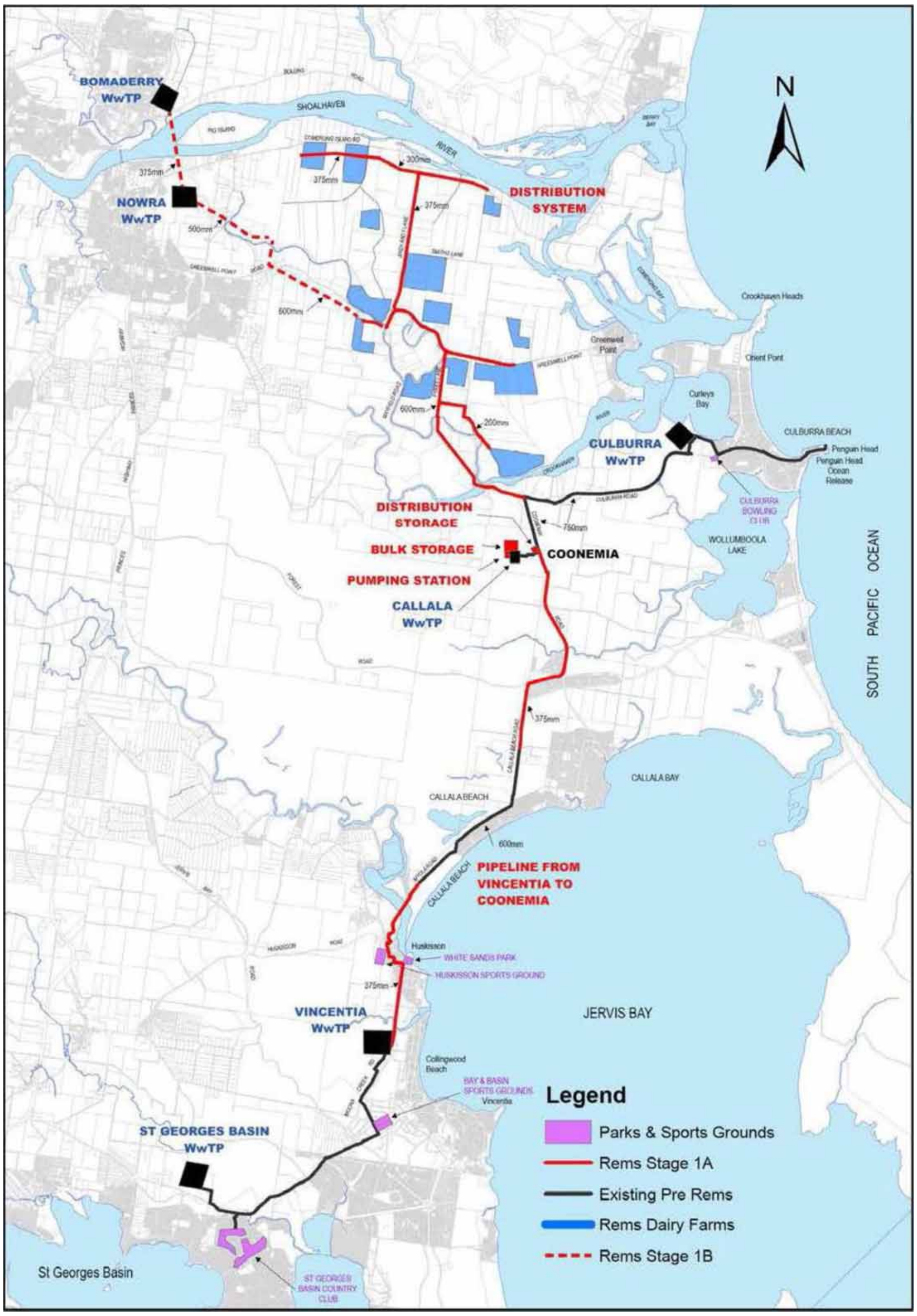

Figure 5 | Diagram of REMS. Stage 1A + Stage 1B, approx. 20 years from physical commencement of Stage 1A to the commissioning of the completed Stage 1B. *Source:* Shoalhaven Water Reclamation Annual Report 2019/20.

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REMS Stage 1A addresses wastewater treatment in the 'Jervis Bay' region and the creation of the farm irrigation infrastructure, and consists of:

- The upgrade of three existing wastewater treatment plants, at St Georges Basin, Vincentia, and Culburra Beach.
- The creation of a new wastewater treatment plant at Coonemia (servicing Callala and Currarong).
- The establishment of a pumping station, distribution storage reservoir and bulk storage dam at Coonemia.
- A pipeline linking Vincentia WWTP to Coonemia.
- A treated water distribution system including holding dams on each farm.

Stage IB involves upgrading the capacity and treatment processes at both the Nowra and Bombaderry wastewater treatment plants, the linking of these two plants via a pipeline beneath the Shoalhaven River, and connecting the plants via pipelines to the existing REMS distribution network.

The completion of Stage 1B enables the whole REMS scheme to deliver nominally 22 megalitres of reclaimed water per day to end users. Stage 1B provides approximately the same volume as that produced by Stage 1A.

In addition to the use of reclaimed water, an objective of the scheme was that the biosolids 'byproduct', created by the treatment and drying of sludge, was to be utilised as spreadable soil conditioner on agricultural land.

While not directly linked to the REMS system, other wastewater treatment plants located within the LGA, at Berry, Shoalhaven Heads, Sussex Inlet, Ulladulla, and wastewater reclamation facility at Kangaroo Valley, all make use of reclaimed water to varying degrees, and contribute to the biosolids resource.

In order to utilise the reclaimed water, the dairy farmers needed to commit to financing irrigation infrastructure; much of this was achieved though a 'buyers group' formed by the pioneer farmers, who collectively researched and identified the best available equipment and negotiated its purchase.

In addition to the capital cost of the irrigation, there were ongoing energy costs to be recognised. The 'early adopters' were assisted with some grant funding to address these costs.

The supplied water had to meet strict water quality targets and a program of on-going water, biosolids, and soil quality monitoring was to be put in place.

The water on farm was to be utilised initially for pasture irrigation.

RESOURCE PRODUCTION

The REMS scheme commenced with the idea of creating two basic resources:

- Tertiary treated reclaimed water suitable for agricultural uses, plus golf course and sporting field irrigation
- Reclaimed biosolids for use as spreadable soil conditioner in agriculture.

Plus, the scheme aimed to identify future uses and evaluate future opportunities.

EVOLUTION AND ADJUSTMENTS

Four years after the commissioning of Stage 1A, the Australian Guidelines for Recycled Water (AGRW) were introduced. These guidelines set a higher standard than the previous requirement. Shoalhaven Water embarked on an upgrade program including the installation of UV treatments that upgraded the system to meet the AGRW standard (McGill *et al.* 2014).

Continuing testing of water quality, soil quality and livestock health backed by transparent reporting and relationship building between the parties fostered trust and consolidated the worth of the scheme.

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As confidence in the system developed, as testing proceeded, and as improvements were made, the scope of utilisation of the treated water was expanded to include hardstand washdown, stock cooling spraying, stock drinking water, and some stock feed crop (maize) irrigation, further increasing the reclaimed water utilisation rate.

The use of biosolids soil conditioner created from 'sludge' extracted from the treatment plants has increased in its acceptance and its application.

There has been interest from a number of 'third party' companies interested in utilising various outputs from the system – solid, liquid and gas. As there are a number of 'commercial in confidence' discussions currently underway we are unable to further discuss this issue at this stage.

FINANCING AND ENABLING

Through strong and patient advocacy by Shoalhaven Water, visible and committed support from Shoalhaven Council, the NSW and Australian governments, a great level of trust had enthused a committed group of pioneer dairy farmers, and given confidence to an interested public. This trust was the basis of enabling of the idea to proceed.

The onset of the Millennium Drought emphasised the timeliness of the opportunity.

On-farm infrastructure, irrigation equipment and so on, was facilitated via a farmers' buying group and assisted with some grant funding.

For the system:

- The base level of funding was to be provided by Shoalhaven Council, with supplementary funding made available via the NSW State government, and the Australian Federal government, plus contributions from irrigators
- The cost burden to the Council had to be carried with a relatively minor increase in sewerage charges, which was supported by the public
- As an incentive to the initial participating landowners, Shoalhaven City Council agreed that reclaimed water would be provided to the farmers at zero cost for an initial 15 year period. This was recently reviewed and agreed that the reclaimed water would continue to be provided at no cost for a further 15 years, to year 2032
- Future funding may also arise from industry partnerships.

As one of the largest water reclamation projects undertaken by a local government in Australia, this is a project of both State and National significance.

IMPLEMENTING THE SYSTEM

REMS Stage 1A was commissioned in January 2002. At a cost of $34 million for plant upgrades, new plant, and linking and distribution infrastructure, reclaimed water was distributed to over 500 hectares of irrigated land comprising golf courses, sporting fields and 14 dairy farms. A usage target was established with the farmers, golf courses and sporting fields.

REMS Stage 1B construction was completed in December 2019, including the comprehensive upgrade and expansion of both Bombaderry and Nowra wastewater treatment plants, the linking of these plant via under-river pipeline, and linking pipelines to the Stage 1A infrastructure. The addition of REMS Stage 1B doubled the capacity of the system output.

In addition to the fixed water infrastructure, a mobile biosolids dewatering centrifuge is part of the system.

Across the REMS irrigation area there are varying soil conditions, some of which benefit from the application of the biosolids soil conditioner, encouraged by the growing confidence in the system.

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Through the use of the mobile centrifuge, 6310 wet tonnes of biosolids, yielded by the treatment plants in 2017/2018, were dewatered and tested (Grade C or better) to become 2850 processed tonnes of soil conditioner, and applied to farmland within the area in October 2017 and April 2018 (Shoalhaven Water Reclamation Annual Report 2018/19).

In the year 2018–19 (a year of below-average rainfall in the LGA) a total of 1900ML of reclaimed water was utilised, being 90% of total scheme outflow for the year.

During this same period, a total of 5910 tonnes of biosolids, having been dewatered, tested and deemed suitable for agriculture were utilised as soil conditioner on local farms, being applied in November 2018 and May 2019.

Biosolids are produced from the sludge harvested from the wastewater treatment plants at approximately 6 monthly intervals. It is processed in the mobile centrifuge unit and stored on-site until dried and tested, any non-compliant material is taken to a waste facility; however, to date there has been a very high level of compliant material that has been made available for soil conditioning.

The dairy industry has undergone significant structural change within this period in both the sale and distribution of milk as well as on-farm management and the scale of operations.

In summary, the co-operative structure has collapsed, the farms have consolidated and herds have increased in size. It is reported that milk yield had increased, and constant daily monitoring of milk and herd quality has been undertaken. The industry has recovered from the millennium drought with the assistance from REMS, with a resilience that has enabled it to address the problems of the most recent drought in the context of the indignity of $1per litre retail price of milk dictated by the major supermarkets.

South eastern Australia had experienced generally drier than average years from 1996 to 2010, with the period between 2001 and 2009 being referred to as the 'Millennium drought'. This period was followed by La Nina conditions in late 2010 and 2011, resulting in high rainfall for the region.

The REMS scheme, having been introduced in 2002, was a significant contributing factor to keeping the dairy industry viable in this region during that period, remembering that up until this time there had been no history of irrigation for dairy farms in this region.

During periods of high rainfall the take-up of the available irrigation water is reduced and there is a consequential increase in ocean outfall discharge (Figure 6).

A similarly significant period of sustained drought occurred from 2017 to early 2020, being followed by intense rain and flooding.

Initially the reclaimed water had been used exclusively for pasture irrigation purposes; however, as time progressed with system improvements and the familiarity and confidence in monitoring, the utilisation spread to washdown, herd cooling spraying and stock drinking, further increasing the general take-up volume.

REMS is subject to an Environmental Monitoring Program, part of which compares soil samples taken from irrigated and non-irrigated farms in order to monitor the effects of reclaimed water irrigation, in particular a build up in soil salinity. The target soil salinity level is : <2 dS/m; the REMS irrigated area has remained well below this level.

As with much of Australia, the Shoalhaven Region, although coastal and temperate, is subject to the extreme swings of drought and flood, and over the period that REMS has been in place, has experienced significant versions of these events.

In times of drought, the reclaimed water is used extensively, in times of high rainfall or flood much of it discharged to the ocean, albeit a discharge of much higher quality than pre-REMS.

The completion of Stage IB delivers far higher volumes into the network, volumes beyond the capacity of the dairy industry to utilise, even with an expanded utilisation to those farms now on the waiting list.

The two decades of implementation has seen the gradual enabling of the integrated system, improvements in technology of treatment, a thorough testing of the robustness of the system, an enormous growth in confidence by the farmers, and a ratification to the public for the support given.

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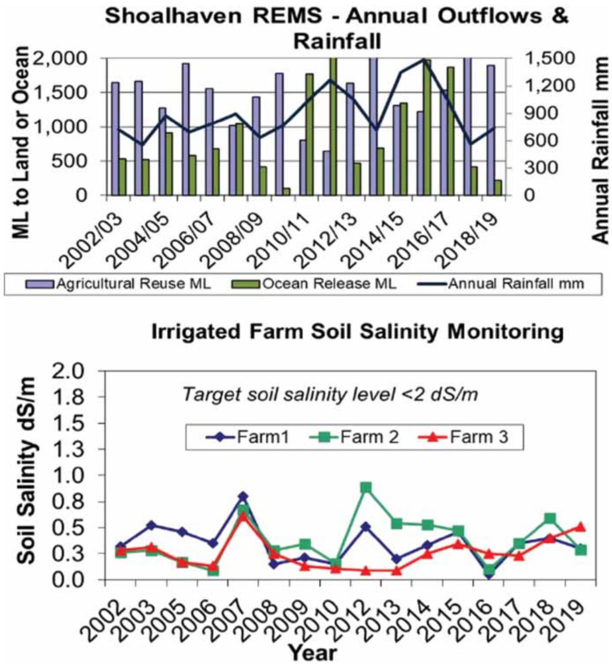

Figure 6 | REMS reclaimed water agricultural re-use + ocean release compared to annual rainfall 2002–2019 (above). Soil salinity monitoring on REMS irrigated farms 2002–2019 (below). For the duration of the REMS soil salinity levels have remained well within the safe irrigation range of <2 dS/m. *Source:* Shoalhaven Water Reclamation Annual Report 2018/19 (both tables + quote).

The environmental outcome of the quality of the reclaimed water produced is extremely significant, benefitting the marine and terrestrial environments and the health of the oyster and dairy industries.

The infrastructure is in place to go further, there are challenges and great opportunities for the scheme to address.

REMS 1A +1B captures sewage from Nowra to Jervis Bay, a general residential population of nominally 60,000 people with capacity to handle 3 times this amount in the summer peak. The system consists of six linked modern tertiary level wastewater treatment plants and a capture, holding, storage and distribution network serving an allocated irrigation area of over 600 ha of dairy farm and sporting fields, plus biosolid processing facilities including a mobile centrifuge. Over twenty 'entities' now participate in the irrigation scheme.

There is now a waiting list for REMS participation by farmers

REMS Stage 2 is currently seeking funding; this will consist of an additional storage dam at Coonemia, increasing the current holding capacity of 600ML by a further 900ML, creating 1500ML of available storage (Shoalhaven Water Reclamation Annual Report 2018/19).

SINCE DECEMBER 2019

After years of drought and water restrictions, bushfires ravaged the Shoalhaven Region for months, destroying wilderness, agriculture, townships and lives. An economy dependent on summer tourism was ruined.

After the bushfires, the drought was abruptly ended by flooding rains that washed the ash and detritus of the fires into the catchment and river system, overflows occurred into the river system and the oyster industry in the river delta was closed down.

By March, Covid19 had a name and the region went into lockdown, into isolation; the tourists who were so desperately wanted after the fires were nowhere to be seen.

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In half a year, the systems had been tested under extreme conditions, and in early August intense rains caused severe flooding in the Shoalhaven, the amount of water spilling over Tallowa Dam in 24 hours represented 20 years of local consumption.

The dams are full: what now for reclaimed water and its byproducts?

This is the cycle of drought, flood and fire, this time complicated by pestilence, but the cycle will continue and is predicted to intensify.

This is the time to plan for this inevitability.

REMS has provided infrastructure that creates a permanent source of valuable reclaimed water, primarily for non-potable purposes. The dairy industry has provided the initial answer to the question of possible uses; however, its capacity to expand to consume the greater volume has been exceeded.

If there is one thing that the pandemic has shown us, it is that there is no point in only having Plan A.

The cycle of drought and flood will continue.

We must examine a range of uses for this valuable resource.

The following are thoughts reflecting on a series of possibilities.

EXPANDED DISTRIBUTION, CO-LOCATION AND ALTERNATIVE USES

The REMS scheme has provided a resource collection, production and distribution network.

It has a stated objective of reducing the discharge of its excess reclaimed water to the environment to the lowest possible level.

It has the capacity to provide guaranteed reclaimed water supply regardless of drought status.

Given the geography of where the scheme currently exists, there appear to be three simple options to further utilise the resource, both water and biosolids:

- *Option One* is to increase the distribution network, either co-ordinated with other infrastructure such as roads, in 'dual pipe' distribution to new developments or distribution upgrades; or in single-purpose easements. As Shoalhaven water is directly owned by Shoalhaven Council, co-ordination of infrastructure can be very direct
- *Option Two* is to intensify the use within the discipline of the existing distribution framework, whether for agriculture, industry, firefighting, transport, recreation, or urban greening and so on.
- *Option Three* is to export the reclaimed water to areas of greater need, either for direct application or for further treatment that may include potable applications.

While the drought has broken in coastal NSW it still exists in some areas beyond the Great Dividing Range and in areas of rain shadow.

Is there an opportunity to export reclaimed water from the Shoalhaven to other parts of NSW, by pipeline or by rail?

Bombaderry is served by a rail line that already distributes ethanol by rail and receives grain for its production by rail, to and from the Manildra Group plant facility, conveniently nearby the Bombaderry wastewater treatment plant.

During the drought, serious consideration was being given to water transport by rail to parts of NSW by other water utilities.

The pipeline distribution can 'piggy back' on proposed infrastructure including bridge and highway work planned for the region. The opportune co-location of distribution networks takes co-ordination but can lead to significant cost savings, utilising the easement and physical construction for mixed purposes, such as road + water + services.

As a replacement for precious potable water, the reclaimed water can be used for industrial and civil purposes, including dust abatement.

A front-of-mind issue looking at very recent (and recurring) history is the issue of **Bushfire defence**.

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Every summer brings with it the risk of bushfires: if this risk falls on the back of a period of drought as it did in the summer of 2019/2020, the outcome can be catastrophic and wide reaching. Firefighting cannot be done using seawater, due to salinity issues, so a network of reclaimed water fed storage areas presents itself as a real possibility.

A permanent network of bushfire defences may be established locally, guaranteed in supply by reclaimed water in a series of storage formats including ones suitable for aerial collection.

For this to be considered the AGRW guidelines would need to be amended to include 'use for fire fighting'.

Aerial collection of water by fixed-wing aircraft has a discipline to it requiring a straight stretch of water over a kilometre long in order to be able to effectively scoop up the required amount.

The construction of strategically placed holding dams could be configured to enable aerial fire-fighting collection, filled with and topped up by reclaimed water.

It is possible to consider such dams as also providing recreation opportunities, including competition/training rowing, canoeing, dragon boating and sailing courses; or for 'landing strips' for float planes; always full and ready to be accessed for fire fighting.

Lake George (a lake near Canberra characterised by long empty spells when it functions as pasture) style recreational storage dams; that is, land that can be used for both water storage and grazing purposes, going through cycles of empty and full, could be employed for periods of flood and excess production.

Expanded Agriculture applications: review ***wider*** agricultural practices that are best suited to the guaranteed water supply and would complement the dairy production, from specific field cropping to hydroponics. This could include diversification on land within the dairy irrigation network; including high water-use crops such as almonds, rice or even cotton. The dairy farmers could be encouraged to enter into alternative cropping or share cropping partnerships.

Forestry (the initial target for the reclaimed water use) could be revisited, examining various timber types.

Industry: identify industries that could be located within the network, or co-located with the treatment plants, which are high water users and may also directly feed the treatment process, the creation of dedicated 'water/biosolids industry' clusters within the network. Some of these are industries that traditionally may have needed to have been located adjacent to a river; others are industries such as energy producers that can take advantage of each stage of the resource creation; and others that could be associated with processing and distribution of the resources, including 'tailor-making' water of different qualities for very specific purposes. Explore industry partnerships.

This would require zoning consideration by the Council.

Byproduct utilisation: exploration of further possible use of byproducts of the process: gas, solid or liquid for utilisation in a variety of applications including energy production.

Firefighting: create firefighting water holding and active firefighting infrastructure, including township defence and tanker filling locations, along the distribution network.

Transport: create collection hubs for road transport as well as at the Bombaderry rail head for effective long distance transport.

Recreation: whether in the creation of new holding lakes that may also provide recreational opportunity, the high water using recreational requirements from initial fills at 'high filtration environments' at aquatic centres, or domestic pools, filled by tanker, through to dedicated recreational water parks.

URBAN ENVIRONMENT GREENING

It is desirable to green the urban environments of cities, towns and villages for both aesthetic and urban cooling outcomes. The recent multi-year drought and its associated water restrictions on potable water use for garden watering and civic irrigation has highlighted the potential for reclaimed water,

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particularly in the civic context, as the water source for this; this is the beginning of a much larger discussion. This process is not reliant solely on pipeline distribution and can be achieved using tankers.

- Tailored water quality: the production of specifically targetted waters for specific applications
- Aquaculture for fresh water environments including algae production, and wetland habitats
- Energy applications such as pumped hydro and hydrogen production
- Contributing water volume to river flushing and environmental flows

These are thoughts that require expansion and a much greater breadth of debate and consideration.

The challenge is to identify those practical uses that can utilise the system output, even if it is given away, because the alternative is that this highly processed resource will simply end up in the ocean (Figure 7).

Figure 7 | Jervis Bay. NSW. Now a Marine Park and National Heritage Area. It was outfall discharge into this sensitive bay that initiated the journey that became the REMS project. *Source:* visitnsw.com.

Promoting the REMS: this is a system that deserves widespread attention, particularly from the agricultural sector and urban centres of all sizes, including the big cities, the integration of sewerage processing, the creation of resources, and the implementation in agricultural and industrial practices. This is an active real-life laboratory that needs to be interactive in a physical and on-line capacity.

THE TOWNSHIP AND AGRICULTURE PRODUCTION RELATIONSHIP

The REMS model is scalable and applicable to townships and cities, the relationship between generation of wastewater by a town or city and the utilisation of this wastewater as a resource, once treated, for agricultural uses, instead of outfall discharge to waterways, suggests a pattern and shape for future development where the agricultural production is directly linked to the water cycle. This presents interesting zoning challenges and opportunity. There is clearly a need to join the discussion about responsible food production in proximity to its consumption and the carbon footprint of excessive transport, this can change our pattern of settlement.

The resource of reclaimed water means nothing without reasonably adjacent productive applications that displace the use of potable water.

REMS WATER: RELIEVING THE BURDEN ON TOWN (POTABLE) WATER, AND OPENING NEW OPPORTUNITIES

All of the dairy farms within the REMS area are serviced by Town Water and all fresh water usage had previously been provided by town water (supplemented by tank and minor dam catchment – for

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which the terrain is largely unhelpful). The Shoalhaven River within the REMS area is tidal and saline, and therefore unsuitable for irrigation. The REMS water has displaced town water on these properties for everything except human consumption.

One of the consequences of the success of REMS, in the creation of an efficient, reliable and effective sewage treatment system, is that it created the potential for the significant expansion of urban development within the region, this being one of its three initial goals.

With a greater population comes greater demand for potable water. The need for greater catchment, treatment and production of potable water to meet these future demands can be offset by the effective utilisation of the REMS water to meet some of the fresh water requirements, other than drinking water, that potable water is currently used for.

During the last twenty years, in eastern Australia, and in this region, there has been a cycle of drought, normal and flood conditions, as we would expect. The drought periods of the millennium drought (early to mid-2000s) and the most recent drought (mid to late 2010s) have been severe, resulting in the imposition of water restrictions on potable water use at times during these periods. These water restrictions are also accompanied by a number of strategies to reduce potable water use generally published by Shoalhaven Water, that the public is now familiar with, that are now seen as good practice: reduced shower times, restricted garden irrigation, domestic water recycling, and so on. The public has become comfortable with these domestic initiatives and also with signs indicating that parks, golf courses and playing fields are irrigated by other than town water (recycled, bore, tank etc.). There is a heightened public consciousness that water usage needs management, and part of that is understanding that potable water is not the only water available for many applications, the public is interested, and water has become a topic of general conversation.

The challenge for REMS beyond 2020

With the opening of REMS Stage 1B in early 2020, the scheme has the potential to produce much more water than the current stakeholders can utilise even in severe drought conditions, the planned Stage 2 sees a significant increase in the holding dam capacity. The water is there to be used, rather than discharged to outfall. This is the challenge for REMS beyond 2020 – optimising the offset to potable water and identifying and encouraging new uses, within an efficient delivery framework. This is an enormous opportunity to harvest this perpetual spring of reclaimed water, capitalising on the base of the existing infrastructure. We refer to a range of opportunities within the body of the text, opportunities that are not limited to this region, but many are applicable wherever appropriate reclaimed water can be made available.

The most immediate beneficial opportunity, in this instance, it would appear to the authors, is to utilise and intensify the existing footprint of distribution, by adding other agricultural uses that are efficient on space, complement the dairy land-use and provide alternative income opportunities for the landholders, and need a guaranteed water supply (hydroponics, market gardens, almonds, rice, cotton etc.). Dairy farming itself is a highly mechanised industry using sophisticated equipment, management strategies and utilises large truck-based distribution, these farmers are familiar with complexity and a 24/7 production cycle. The water utility already has a long-established working relationship with the dairy farmers, enjoying a very productive dialogue. The region is temperate, has a developed distribution network, using truck rail and potentially air, and is immediately adjacent to an expanding large township and three major cities.

There has to be a multiplicity of options available that not only capitalise on the REMS output, but provide a model for use elsewhere, where urban wastewater can become modern agriculture's reclaimed water.

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IN SUMMARY

The whole of the Shoalhaven LGA provides a very interesting case study and is in many instances a widely applicable series of models for further development.

Environmental sensibility; development pressure; townships of varying scales; transport opportunities; agriculture of various types; tourism; a diversity of geography, coastal, wilderness and varying terrain.

The REMS scheme is a remarkable and timely 20-year achievement by a local council and its integrated water utility.

It is a comparatively simple real-life example that is a scalable enterprise that is applicable across Australia and other parts of the world.

Its success to date has relied on a profound informative engagement process of public, stakeholders and government; coupled with very strong advocacy from utility management and 'early believer' farmers and its application in an agricultural use environment (Mooney & Stenekes 2008).

Continuing visibility, accountability and strong advocacy will be required to reach its full future potential.

REMS provided confidence and belief in the future for the dairy industry, resulting in commitment to investment, increased production and herd size.

The public have remained in support of the process as the success of the application of reclaimed water for agricultural purposes has been 'proved up'.

It has addressed the issues associated with productively dealing with effluent, following a substantial increase in population and has facilitated future growth in a sustainable manner (Figure 8).

Figure 8 | REMS Stage 1B declared open, thirty years and approximately $150M after initial discussions.

It has provided protection to sensitive marine environments including the Marine Park of Jervis Bay and oyster industry of the Shoalhaven/Crookhaven delta.

It may also have provided a strong model for the relationship between agriculture and urban centres in future town planning models.

The challenge is to maintain innovation, and to maintain public dialogue and to seek further applications within and beyond the agriculture sector.

I note by way of simple observation that the journey that resulted in the REMS scheme would not have received nearly the level of public support had the emphasis not been on the utilisation of the treated effluent for agricultural and civic purposes.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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