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Department of Agriculture and Water Resources

Pork water balance model development

Final Report
APL Project 2018/0003

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Department of Agriculture and Fisheries
Alan Skerman
PO Box 102, 203 Tor Street
Toowoomba QLD 4350

DHM Environmental Software Pty Ltd
David McClymont
9 Alford Street
Toowoomba QLD 4350

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Executive Summary

Piggery effluent storage and use systems need to be designed and managed to minimise the risk of overtopping (or spilling) and thereby releasing effluent containing nutrients and pathogens into adjoining properties or downstream aquatic environments. This is particularly critical following major rainfall events and during periods of extended wet weather, when the soil in the effluent reuse area is too wet to allow effective effluent irrigation. State and local government regulatory agencies generally specify a minimum average spill recurrence interval (typically ten years) to minimise the risk of spilled effluent contaminating surface water and/or groundwater resources. This design standard may be varied depending on the sensitivity of the receiving environment.

Monthly water balance modelling is sometimes used for designing effluent storage systems to meet the relevant regulatory standard for the spill recurrence interval. However, it is widely recognised that the most comprehensive and realistic design method involves using a daily water balance approach, based on historical daily climatic data recorded over an extended period for the piggery locality. This design approach involves processing large amounts of data, requiring the use of a suitable computer model.

The *WatBal* computer model described in this report, was developed in response to a need identified by APL for a relatively simple, widely accessible, daily water balance model, designed specifically for modelling Australian piggeries. It is anticipated that it will assist individual producers negotiating planning approvals for new and expanding piggeries, in addition to supporting the expansion and consolidation of the pork industry across Australia. he user-friendly, web-based format of this model will assist both the consultants involved in preparing proposals for new developments, and the regulatory officers who are responsible for assessing development approval applications. Ultimately, nearby landholders and the general public will be more confident that new piggery developments have been designed to minimise the risk of environmental contamination resulting from excessive spillage of effluent storage ponds. This will in turn enhance the social, environmental and marketing credentials of the Australian pork industry.

The calculator is available at: https://watbal.australianpork.com.au/

A tutorial for how to use the calculator is available at:
https://watbal.australianpork.com.au/About/Tutorial

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1. Background to Research

Effluent discharged from conventional piggery sheds (flushing, static pit or pull-plug systems), is generally directed into a primary anaerobic pond. These ponds are designed to have sufficient capacity for sustaining the microorganisms which break down the organic matter in the pond influent, and for storing the sludge (solids) which settles on the base of the pond. Additional storage capacity is required to hold effluent following treatment. A portion of the stored effluent subsequently evaporates from the pond surface while much of the remaining effluent is commonly recycled for use as a shed flushing medium, or for carefully managed application (irrigation) onto land growing crops and/or pastures. The majority of medium to large-sized Australian piggeries employ a secondary pond to store the effluent. The effluent level in the primary pond generally remains relatively constant, overflowing into the secondary pond by gravity. Alternatively, the effluent storage capacity may be provided in the primary anaerobic pond (single pond), mostly at smaller piggeries.

Effluent storage systems need to be designed and managed to minimise the risk of overtopping (or spilling) and thereby releasing nutrients and pathogens into adjoining properties or downstream aquatic environments. This is particularly critical following major rainfall events and during periods of extended wet weather, when the soil in the effluent reuse area is too wet to allow effective effluent irrigation. If the soil water storage profile in the effluent application area is relatively full, further application of effluent onto this area will result in runoff and/or leaching, and possible export of nutrients and pathogens, which may contaminate surface water and/or groundwater resources. Regulatory agencies generally specify a minimum average spill recurrence interval (typically ten years) to minimise the risk of spilled effluent contaminating the surrounding environment. This design standard may be varied depending on the sensitivity of the receiving environment.

Monthly water balance modelling (e.g. Section 2.6, Birchall et al., 2008) is sometimes used for designing effluent 'wet weather' storage systems to meet the relevant regulatory standard for the spill recurrence interval. However, it is widely recognised that the most comprehensive and realistic design method involves using a daily water balance approach, based on historical daily climatic data recorded for the piggery locality, over an extended period (generally of at least thirty years). This design approach involves processing large amounts of data, requiring the use of a suitable computer model.

The *WatBal* model described in this report, is a relatively simple, widely accessible, daily water balance model, developed specifically for modelling Australian piggeries. It is anticipated that it will assist individual producers negotiating planning approvals for new and expanding piggeries, in addition to supporting the expansion and consolidation of the pork industry across Australia. he user-friendly, web-based format of this model will assist consultants involved in preparing proposals for new developments and the regulatory officers who are responsible for assessing the resulting development approval applications. Ultimately, nearby landholders and the general public will be more confident that new piggery developments have been designed to minimise the risk of contaminating the environment by excessive spillage of effluent storage ponds. This will in turn enhance the environmental and marketing credentials of the Australian pork industry.

2. Objectives of the Research Project

The major objective of this project was to develop a daily water balance model to realistically model effluent collection, treatment, storage and use at Australian piggeries.

3. Introductory Technical Information

Over recent decades MEDLI version 1.3 (Gardner et al., 1996) was used by a limited number of consulting firms for daily water and nutrient balance modelling to support development applications for new piggery proposals across Australia. MEDLI Version 1.3 was developed under the Windows 95 and NT operating systems and was not compatible with later versions of the Windows operating system. This was a major limitation for the ongoing use of this model. While MEDLI version 1.3 included provisions for estimating piggery waste stream constituents, most users preferred to enter waste stream details estimated using more recent versions of the PigBal model (Casey et al., 1996 or Skerman et al., 2013) which were thought to provide more accurate estimates.

MEDLI v2 was released in 2015. This is a fully updated version of the model which is compatible with contemporary Windows operating systems; however, it does not include any provisions for estimating piggery waste stream constituents.

Neither of the previous versions of the MEDLI model included any provisions for modelling runoff from outdoor catchments. While most intensive piggeries have minimal outdoor catchment area contributing runoff into the piggery effluent system, some farms may have, for example, some outdoor dry sow accommodation, or perhaps it may be impractical to divert runoff from some of the grassed area between sheds, or the shed rooves, away from the effluent system. Furthermore, over recent years, there has been increasing interest in outdoor pig production. In some cases, development approvals issued for these piggeries may require the construction of holding ponds to store potentially contaminated runoff from heavily stocked paddocks and range areas.

It is anticipated that a new version of the MEDLI model will be released later in 2019. This version will incorporate a beef cattle feedlot module which will include provisions for modelling runoff from several different outdoor catchments. While this new version of the model will not include any provisions for estimating piggery waste stream volumes and constituents, it may be possible to adapt model inputs to accurately model piggery scenarios which include some outdoor production components.

The original WaterBal model (Skerman, 2001) was developed to assist in designing effluent systems on Queensland dairy farms. While it was used extensively for this purpose, it was never developed to a commercial standard and was not widely released outside the Department of Agriculture and Fisheries (DAF).

In 2014, Dairy Australia identified a need for a national, daily time-step model to augment the existing monthly time-step model included in the Effluent Toolkit (McDowell, 2009 and Birchall and McDowell, 2016), and subsequently provided funding assistance to upgrade the original WaterBal model to provide a national effluent storage design tool. The upgraded version of the model was designated *WaterBal 5* (Skerman and Simpson, 2014). During 2016, a number of revisions and additional features were identified to improve the model's usability and application to a wider range of possible dairy effluent system design and operating scenarios. Consequently, an upgraded version of the model, designated *WaterBal 6* (Skerman and Simpson, 2017), was developed with further funding assistance from Dairy Australia. The WaterBal model has been used extensively for designing dairy effluent systems in Australia and is included in a nationally recognised Design Livestock Effluent Systems course (Unit AHCLSK 506A) delivered by Agriculture Victoria in partnership with Dairy Australia and coordinated by Scott Birchall (AgSystems Design, Shepparton, Victoria).

The current *WatBal* model (Skerman and McClymont, 2019) described in this report, was specifically developed in response to a need identified by the pork industry, for a relatively simple, widely-accessible, daily water balance model, suitable for modelling Australian piggeries. It combines the spreadsheet-based pond design and management equations used in the WaterBal model, with the soil water-balance model incorporated in the HowLeaky application (McClymont et al., 2006) which is one of several agricultural software applications successfully developed by DHM Environmental Software (Toowoomba, Queensland).

4. Research Methodology

4.1 Daily water balance modelling elements

Figure 1 is a schematic drawing showing the various water balance modelling elements included in the *WatBal* model described in this report. In summary, *WatBal* includes provisions for modelling additions to the effluent stream from piggery manure, waste feed, fresh and recycled flushing and hosing water used for shed wash-down, any runoff from shed rooves or outdoor production areas, drinking water wastage, and rainfall falling onto pond surfaces. Effluent system extractions incorporated in the model include evaporation from pond surfaces, and use of recycled effluent for shed cleaning and application (irrigation) onto land growing crop and/or pasture. A daily water balance for the soil in the effluent application area is used to trigger effluent application to land, when the soil water deficit reaches a selected value. This soil water balance allows selection of a range of typical crop/pasture species growing on a selection of different textured soil types in the application area. The model uses historical daily climatic data which is conveniently downloaded from the SILO climate data website (https://www.longpaddock.qld.gov.au/silo/). An interactive map is provided to assist the user in selecting the most representative climate data recording station located near the piggery site. The model accommodates analysis periods commencing from 1900 up until the day prior to the analysis.

Other features of the model include:

- Ability to model a single effluent treatment and storage pond and two ponds operating in series (primary anaerobic treatment pond + effluent storage pond)
- Several common effluent pre-treatment/solids separation options
- A range of primary anaerobic pond design options, including conventional large ponds (ASABE, 2011), heavily loaded anaerobic (HLA) ponds (Skerman et al., 2008) and covered anaerobic ponds (CAPs)
- Provision for shandying (diluting) effluent by mixing with clean water prior to application to land
- Various effluent irrigation management options, including variable soil moisture trigger levels and maximum daily application volumes
- Ability to model evaporation pond systems which do not employ effluent irrigation.

Piggery shed effluent
Manure, flushing, hosing, waste feed, waste drinking water, pit recharge

- Flushing
- Pull plug
- Static pit

Outdoor catchment runoff

- Concrete
- Earth
- Hard
- Grass
- Roof

Effluent pre-treatment / solids separation

- Settling basin
- SEPS
- Static rundown screen
- Vibrating screen
- Screw press separator
- Baleen filter screen
- Rotating screen
- Other

Primary anaerobic pond
(Active treatment + sludge storage)

- Conventional 'large' (RDS)
- Heavily loaded (HLA)
- Covered (CAP)

Secondary storage pond
(Residual and active storage)

Effluent recycling for shed cleaning

Effluent irrigation area

- Range of soil textures
- Range of crop/pasture options
- Soil moisture balance
- Irrigation triggered by soil moisture deficit
- Effluent shandying options

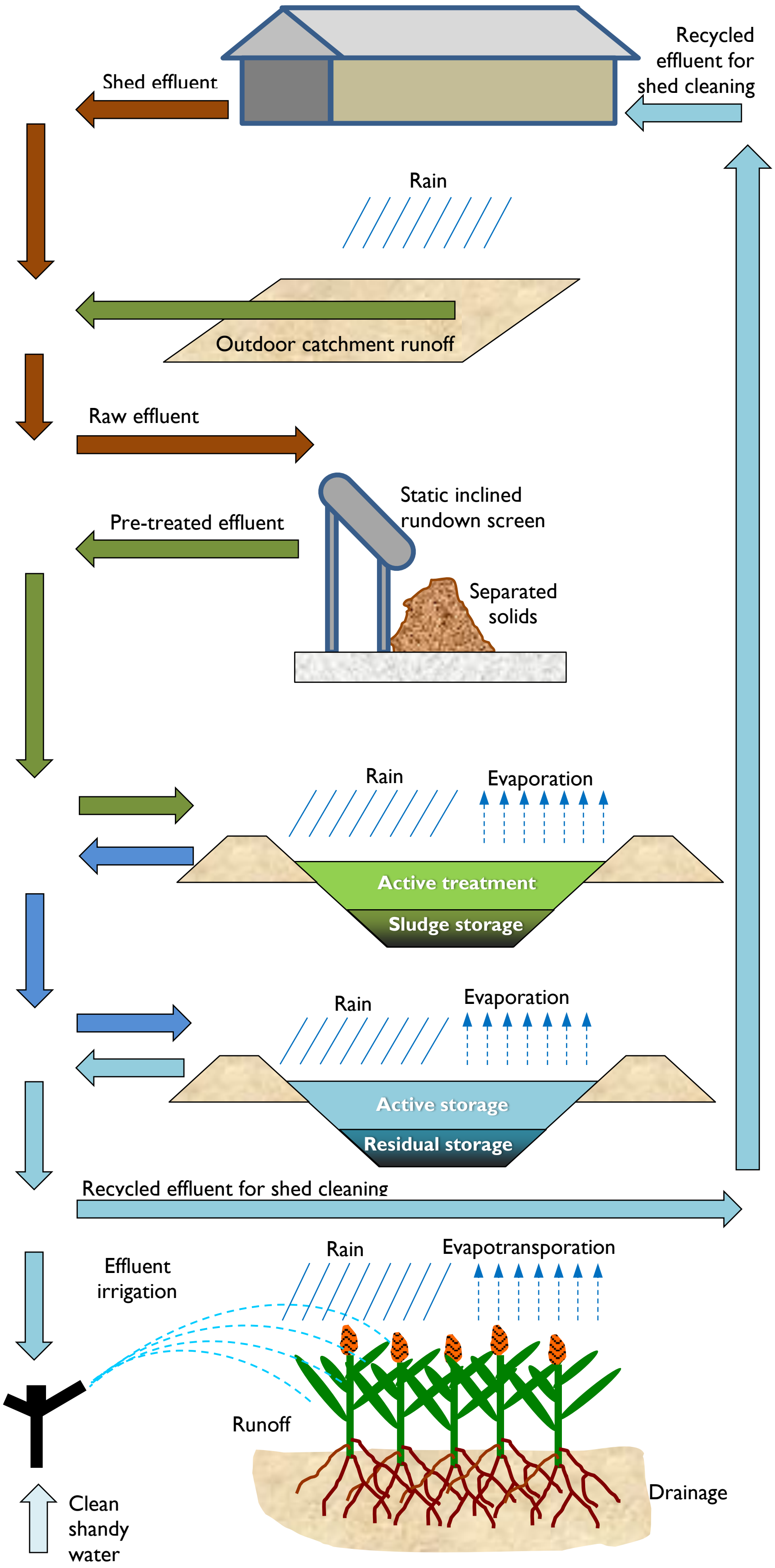


Figure 1 Schematic drawing showing the various elements of the daily water balance incorporated into the WatBal model

4.2 Program development

4.2.1 WatBal website

It was recognised that a web-based model would have significant advantages over the previous spreadsheet versions, particularly with regard to accessibility, model revision and issues with sharing the large files associated with the previous WaterBal models. The *WatBal* website (http://web9.dhmsoftware.hypervps.com.au/) was subsequently developed by DHM Environmental Software Engineering Pty Ltd using the Microsoft .Net NET Core libraries (https://dotnet.microsoft.com), C# for the server code and HTML 5 for the front-end code. Development involved extracting the formulas and equations from the pre-existing WaterBal spreadsheet and combining this with the *HowLeaky* (McClymont et al., 2006) simulation engine (http://howleaky.net) to simulate pond management and irrigated cropping. This was encapsulated within a custom-built website containing a wide range of content-, user- and administrative-tools, and is interfaced through a custom dashboard displaying inputs and outputs for any simulation.

4.2.2 HowLeaky model

The *HowLeaky* simulation engine is a recently-developed daily time-step water balance model that derives from and extends the *PERFECT* model (Littleboy et al.,1992) of the 1980s and 90s. *HowLeaky* (McClymont *et al*., 2006) has been designed to assess the impacts of different land uses, soil conditions, management practices and climate-types on water balance and water quality. It can provide reliable and flexible results from limited input data for a wide range of land use studies. It has been incorporated in stand-alone PC-based software and also into a range of web and mobile applications (i.e. http://climate.net.au and http://soilwaterapp.net.au).

4.2.3 WatBal model development

The new *WatBal* model combines the spreadsheet-based pond design and management equations in *WaterBal 6P.03* (Skerman, 2017) with the *HowLeaky* water-balance model, to simulate irrigated cropping. This involved developing a new simulation engine that provides the initial static calculations for estimating pond dimensions before calculating pond and paddock water-balance on a daily time-step. The model calculation process is shown in Figure 2.

Pond design and management equations have been extracted from the *WaterBal 6P.03* spreadsheet using semi-automated code generation tools to minimise developer effort and errors. This includes both parameter extraction (name, default value, type and description) and formula extraction for non-time series variables.

The *HowLeaky* model was then modified by replacing the existing irrigation storage module with the new effluent pond model. During irrigation, the model checks that there is sufficient water available in the pond from which to irrigate, following the removal of effluent used for shed flushing and pit recharge. The *HowLeaky* Pesticide, Fertiliser, Solute, Erosion and Tillage modules were removed and only the "cover-model" for vegetation was included. The remaining modules in the model (including the water-balance) remained unchanged.

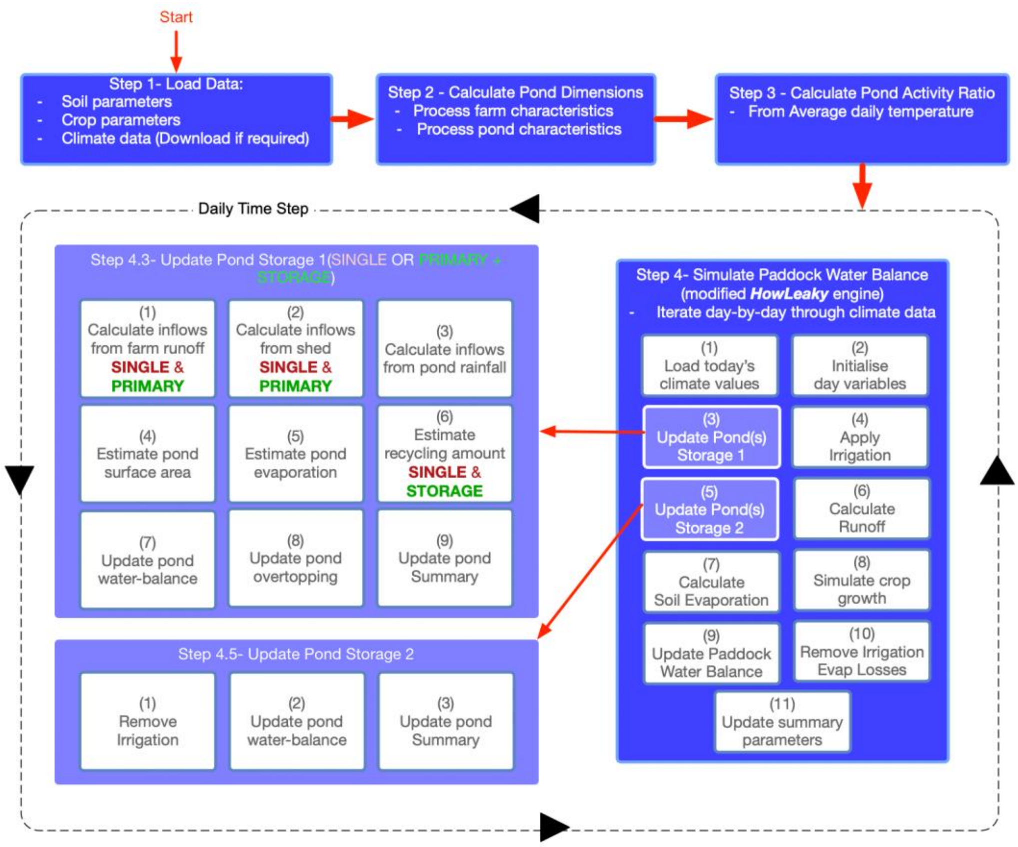


Figure 2 Calculation process in WatBal

4.2.4 *Model parameterisation*

Model parameterisation of both input and output variables is now customisable via the administrative end of the website. These tools provide limited functionally for administrators to edit key characteristics of each parameter such as name, description (tool-tip text), input range and step-size.

4.2.5 *Model inputs*

The original *WaterBal 6P.03* spreadsheet contained over 90 input parameters for the user to populate, spanning six to seven spreadsheet pages. Therefore, the challenge for this build was to simplify these inputs and present them in an intuitive manner on a single "dashboard screen". Our solution was to have a tabbed input panel (Figure 3) with parameters grouped according to:

- Analysis setup (run name, farm name, pond system, climate station location, soil, crop, simulation period, notes)
- Pond catchment (concrete, earth, hard, grass and roof)
- Flushing system (standard pig units [SPUs], management)
- Pull plug (SPUs, management)
- Static pit (SPUs, management)
- Solids management (TS and VS loading from sheds, solids separation options)
- Primary pond + storage pond or single pond (capacity, key dimensions)
- Irrigation (method, area, pump capacity, soil moisture deficit trigger, shandying)

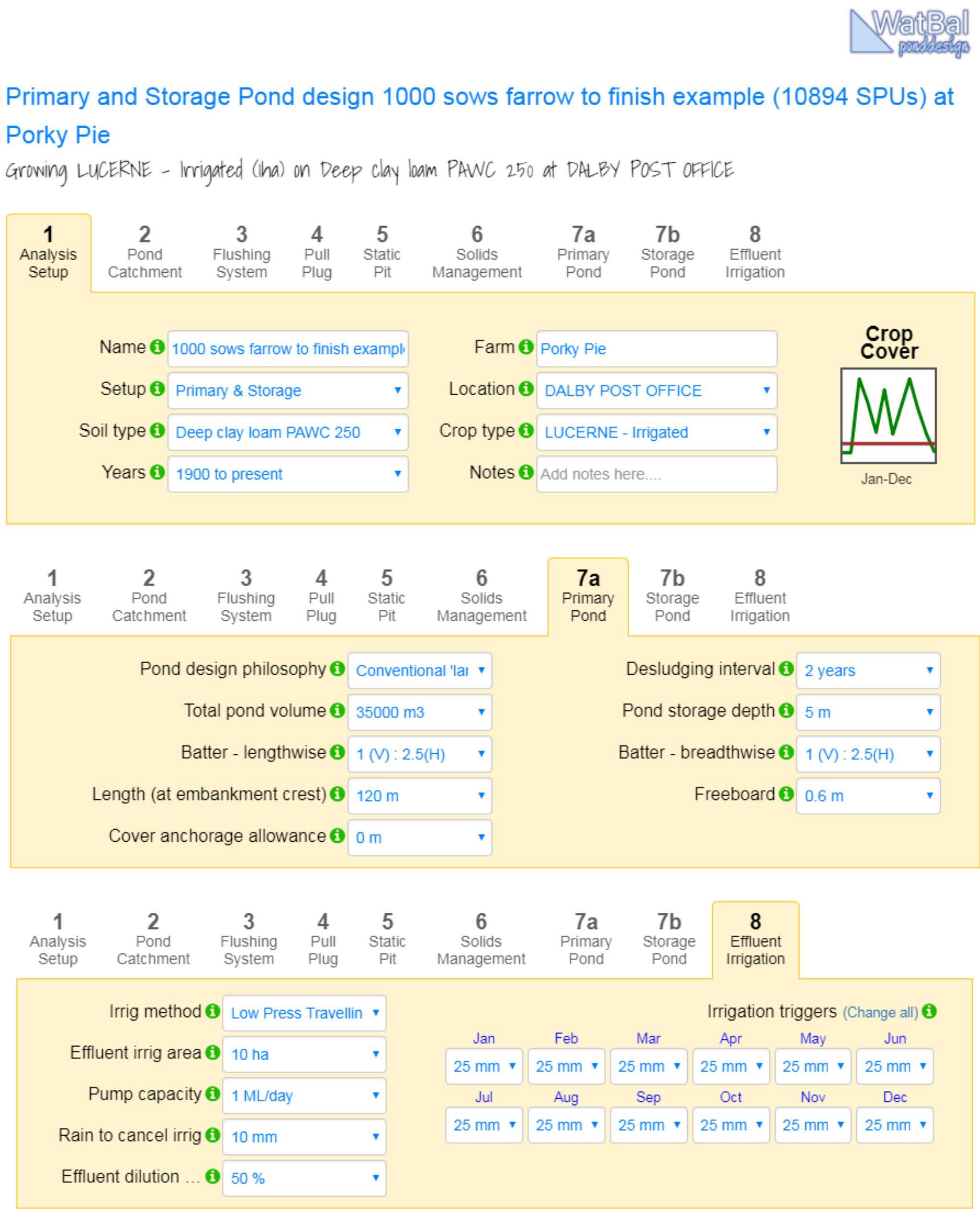


Figure 3 Examples of tabbed input panels

We were able to cut down the number of inputs from over 90 to less than 70, with no loss of functionality. Much of this was achieved by "templatising" soil and crop parameters (user selects only a soil name and crop name) as well as rethinking the irrigation inputs by aggregating some parameters. In addition, inputs are prepopulated each time a user creates a new analysis with initial values sourced from the previously run analysis.

Detailed guidance on the selection of model input values is provided within the model user interface by scrolling over the green ℹ icons. A listing of relevant scientific references is provided in the *WatBal* reference library which may be accessed from the main toolbar.

4.2.6 Simulation outputs

WatBal produces a range of graphical and textural outputs. The key outputs are presented on the analysis "dashboard" (Figure 4) and include:

- Graphical representation of ponds with key dimensions and volumes
- Monthly pond storage levels (mean, 80 percentile and 33 percentile bands)
- Table of storage/single pond water balance components
- Monthly irrigation amounts (mean, 80 percentile and 33 percentile bands)
- Interactive daily time-series chart which show storage/single pond levels, overflows, soil-water, rainfall and irrigation

The analysis "dashboard" presents a simulation on a single screen, with the top section containing inputs and the bottom section containing outputs. Inputs are prepopulated and the simulation runs automatically each time any of the inputs are changed. In addition, a narrow side-panel is presented with an index of the user's saved simulations as well as buttons to add or delete analyses, and to navigate back to the full list.

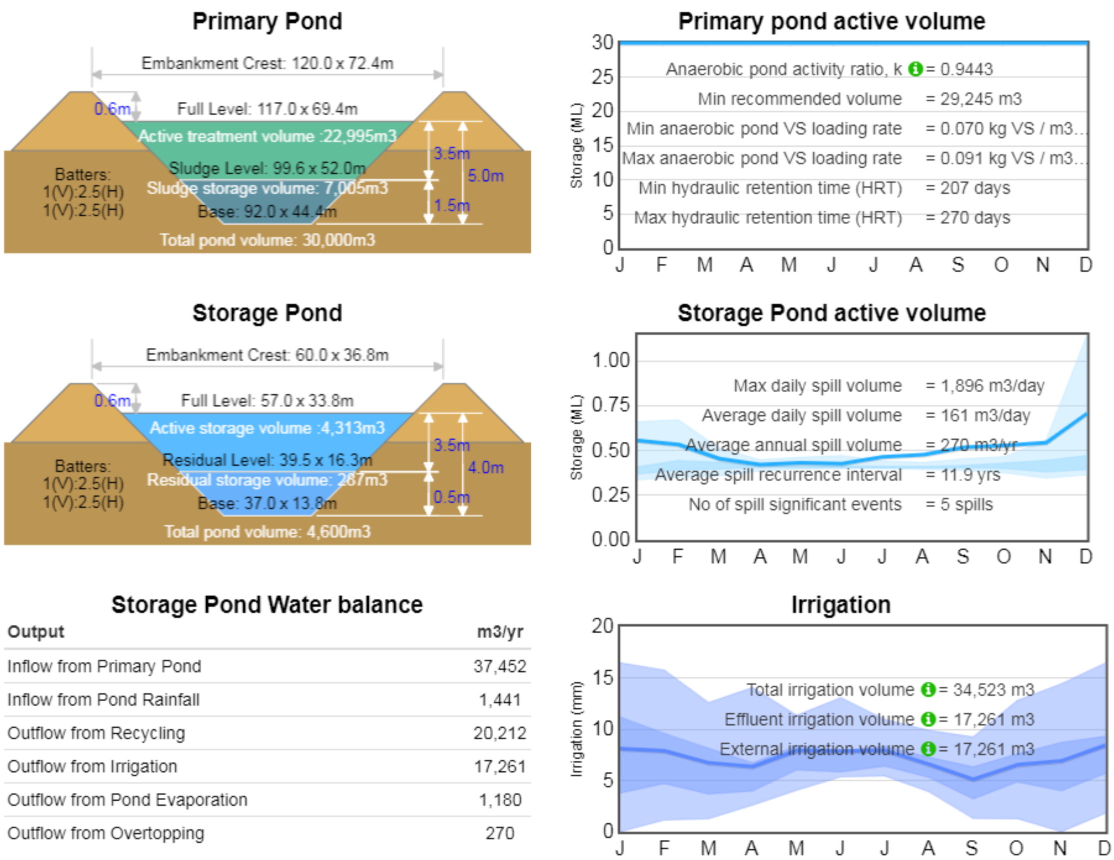


Figure 4 Sample analysis dashboard outputs.

The time-series graphical outputs have a convenient zoom function which allows users to closely examine the pond performance over short-term periods of particular interest (Figure 5). The model also provides a paddock water balance summary for the effluent irrigation area (Figure 6).

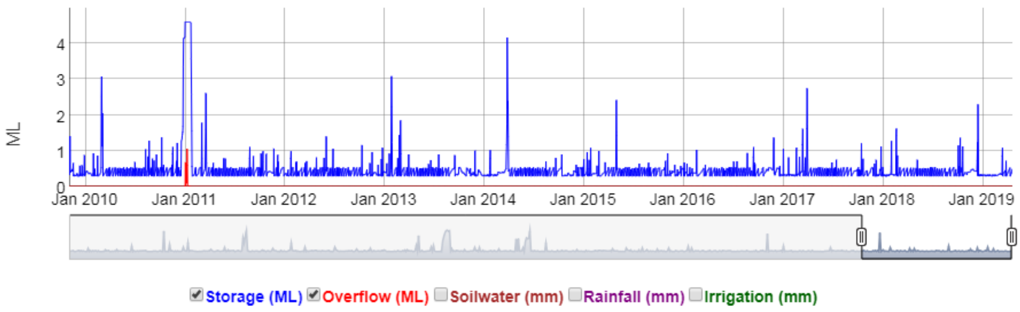
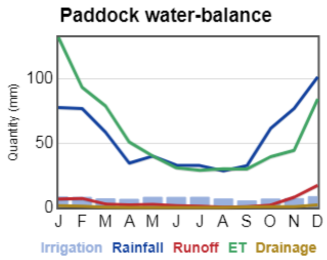


Figure 5 Sample time series outputs.

▾ Paddock Summary



Key time-series outputs

Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Irrig(Total)	8	8	7	6	8	8	8	7	5	7	7	8	86
Irrig(Pond)	4	4	3	3	4	4	4	3	3	3	3	4	43
Irrig(Clean)	4	4	3	3	4	4	4	3	3	3	3	4	43
Rainfall	78	77	58	34	40	33	33	29	33	61	77	101	653
Runoff	7	7	3	2	2	1	1	0	1	2	8	17	51
ET	132	93	79	51	40	31	29	30	30	39	44	84	682
Drainage	1	1	0	0	0	0	0	0	0	1	1	2	6

Figure 6 Sample paddock water balance output.

In addition, the majority of the outputs presented in previous *WaterBal* spreadsheet models are accessible via a collapsible accordion list at the bottom of the "dashboard'. The model also allows the user to download a detailed report in pdf format for all model runs.

4.2.7 *Analysis listing*

WatBal allows users to save and compare a range of scenarios. This is presented as either a table of filtered results (Figure 7) or as filtered mini-reports (Figure 8) showing key analysis outputs.

Name	Farm	Pond Type	Crop	Size m3	Area ha	Spill Recurrence mths	Apill Amount m3/yr	Irrigation Amount m3/yr	Last Modified	
1000 sows farrow to finish example	Porky Pie	Primary & Storage	Summer reduced till C	4600ML	40ha	12mths	270m3/yr	17,261m3/yr	23/04/2019 1:08:09 AM	🗑
Final Report Grower Unit Scenario	Porky Pie	Primary & Storage	LUCERNE - Irrigated	26200ML	10ha	12mths	473m3/yr	28,425m3/yr	31/03/2019 11:16:04 PM	🗑
Final Report Grower Unit Scenario - Single pond	Porky Pie	Single Pond	Perennial pasture-summer active	90000ML	40ha	none	none	29,452m3/yr	31/03/2019 11:16:28 PM	🗑
Test 1 - 26 Feb 2019	Porky Pie	Single Pond	Summer reduced till C	210000ML	50ha	none	none	46,729m3/yr	31/03/2019 11:16:41 PM	🗑

Figure 7 Sample tabular listing of analysis results.

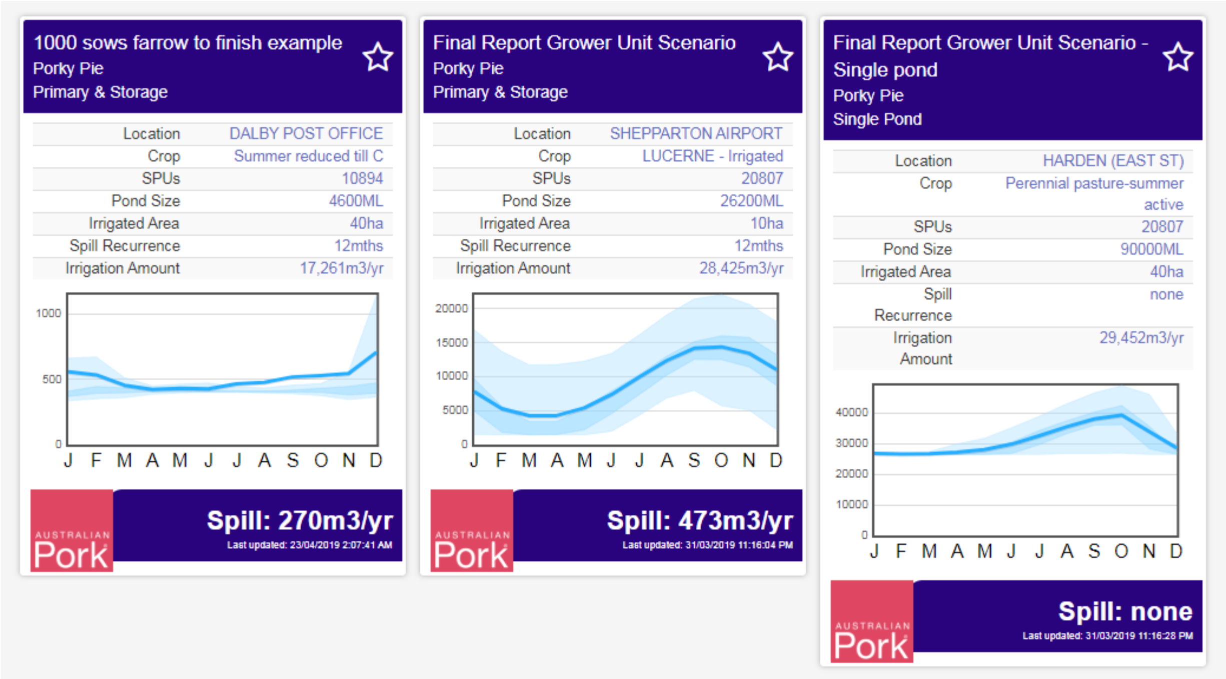


Figure 8 Sample analysis mini reports.

4.2.8 *Website functionality*

The website contains the following services in addition to the simulation functionality:

- "Home" page giving a software description, corporate logos and news headlines
- "About" pages containing overview, copyright, disclaimer, privacy, licensing, development and reference information
- "News" pages including archived news items and the headline shown on the "Home" page
- "Library" page for adding *Word* documents, PDFs, *PowerPoint* presentation/s and embedded videos providing further information relating to the model.
- "Links" page for listing other related websites
- "Contact" page with embedded forms for sending emails to the site administrators and Google "Captcha" functionality to minimise "spam"

An administrative "backend" is also provided for use by the designated site administrators. Pages include:

- "Dashboard" displaying an overview of the site usage
- "Users admin" to manage user accounts and roles
- "Site Content" to author and revise the landing (home) page, about pages and contact info content
- "Site Services" to author news, links, library documents and help documentation
- "Analysis Data" to administer soil, crop and climate records
- "Settings" to administer all model input and output parameters, include names, value ranges and comments (tooltip info)
- "Analytics" to monitor basic site analytical data, including registrations, accesses and analyses

4.3 Model testing

Members of the project team carried out comprehensive model testing during the development phase of the project. In addition, several experienced industry service providers (consultants, researchers and regulators) were invited to review and/or beta test a prototype version of the *WatBal* model prior to its formal release. Issues and features identified in the feedback, comments and suggestions received from these service providers were carefully considered and incorporated into the model, wherever possible.

5. Results

5.1 Piggery scenario

A realistic piggery scenario has been modelled using the *WatBal* model to demonstrate the modelling capabilities and results. Details of the piggery are as follows:

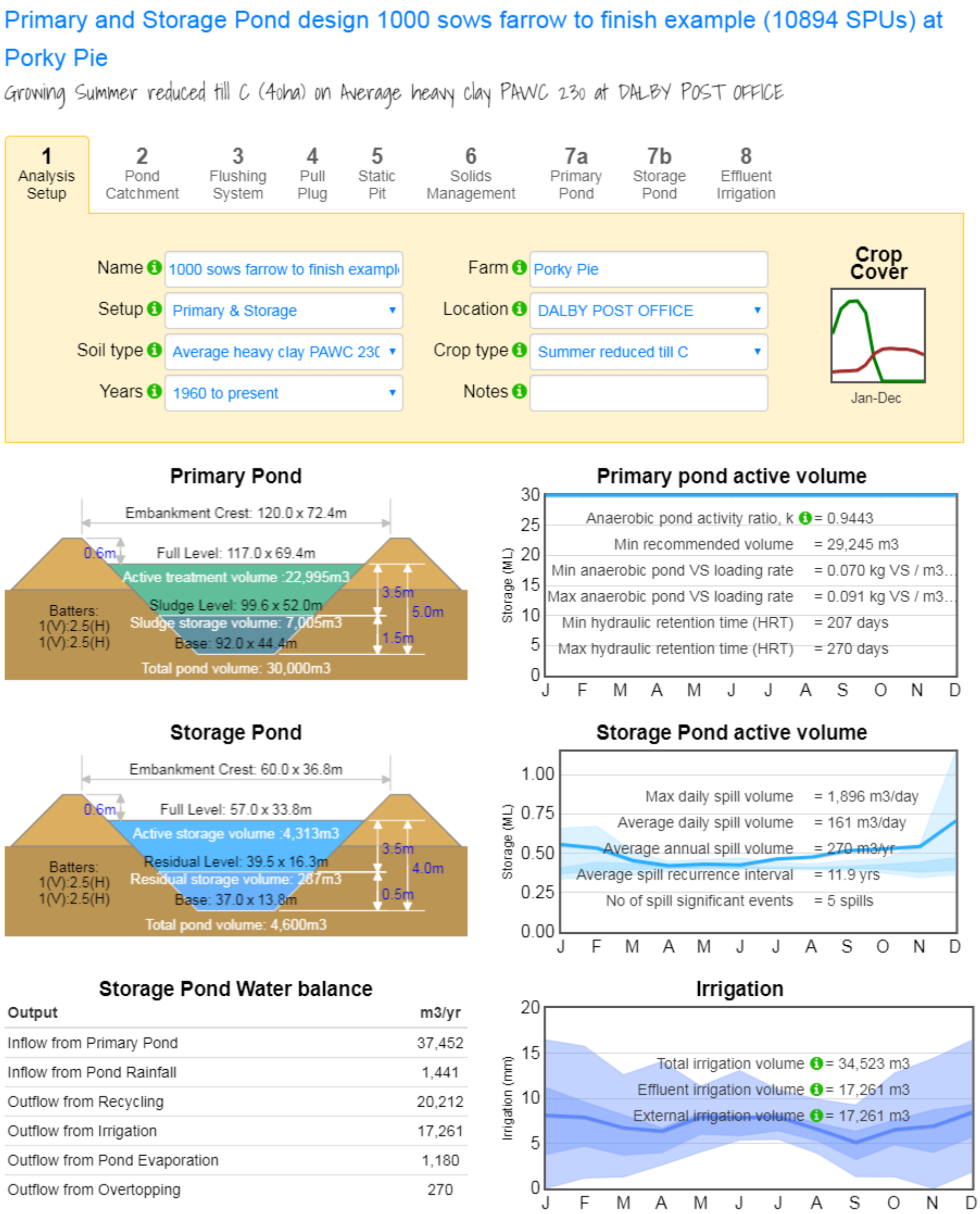
The 'Porky Pie' piggery is a 1,000 sow, farrow-to-finish unit (10,896 SPU) unit, located near Dalby, Queensland; turning off 22,085 finisher pigs annually, at an average age of 22 weeks and an average live-weight of 104 kg (average daily gain: 663 g/day, birth to 100 kg). The piggery feeds approximately 6,643 t of a predominantly sorghum/wheat diet to the pigs annually. All farrowing and dry sow sheds at this piggery are flushed daily, using 19,000 L/day of recycled effluent from the secondary pond. A further 35,000 L/day of fresh water is used for hosing these sheds, once weekly. The weaner, grower and finisher pigs are housed in pull-plug sheds. The effluent is released from these sheds at fortnightly intervals. After the effluent is released from these sheds, the pits under the sheds are recharged with 532,000 L of recycled effluent. An additional 63,000 L of fresh water is used to hose out the pull-plug sheds, once weekly. Because of the terrain and plumbing arrangements at the site, some outdoor catchment areas drain into the effluent system. PigBal modelling suggests total solids (TS) and volatile solids (VS) loadings of 3,500 kg TS/day and 2,800 kg VS/day, respectively, discharged from the piggery sheds, assuming typical feed wastage rates. A static rundown screen is used to pre-treat the shed effluent prior to discharge into the primary pond, which is designed as a conventional large pond, with a five year desludging interval. The secondary storage pond must be designed to give an average spill recurrence interval greater than 10 years, to meet minimum local government and EPA regulatory standards. Excess effluent is pumped from the storage pond to a 40 ha effluent irrigation area growing predominantly summer crops (reduced tillage) on a heavy clay soil with a plant available water capacity of 230 mm. The effluent is 'shandied' (diluted) by mixing with clean bore water at a rate of 50% effluent to 50% clean water in the irrigated mixture.

5.2 Modelling results

According to the model outputs, the conventional large primary pond requires a sludge storage capacity of 7,005 m^3 for the proposed five year desludging interval, and a minimum active treatment volume of 22,240 m^3, based on the calculated anaerobic pond activity ratio of 0.94 for the site. The selected total volume of the primary pond (30,000 m^3 = 30 ML) is greater than the sum of the above components and therefore sufficient for the proposed piggery, giving a maximum VS loading rate of 0.091 kg VS. $m^{-3}.d^{-1}$ and a minimum HRT of 207 days.

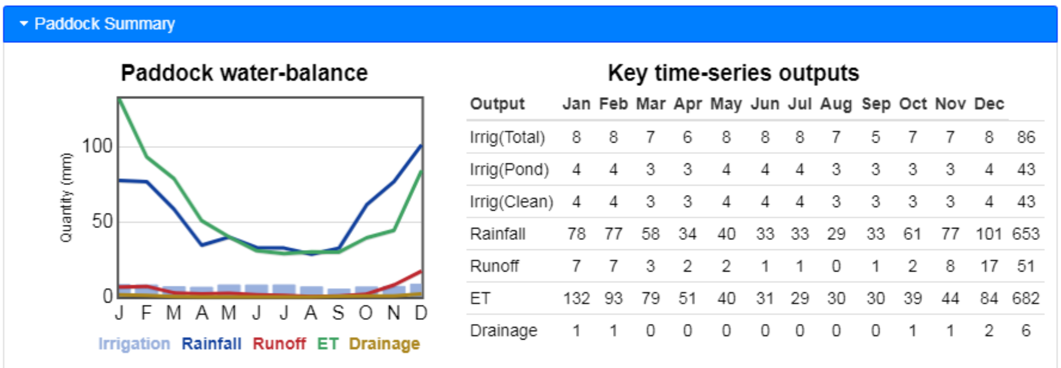
Secondary ponds are generally designed by iteratively adjusting the pond volume and dimensions in conjunction with various effluent irrigation parameters, primarily the irrigation area, pumping capacity, crop/pasture species and the soil moisture deficit used to trigger effluent irrigation. In this case, a secondary storage pond capacity of 4,600 m^3 (4.6 ML) resulted in an average spill recurrence interval of 11.9 years over the 59 year analysis period, from 1960 to 2019. This result is based on applying effluent to the 40 ha area growing predominantly summer crops on a heavy clay soil. Effluent irrigation is triggered at a soil water deficit of 25 mm below field capacity (drained upper limit) and the irrigation pumping rate is 1 ML/day (11.6 L/s).

Further details of the analysis results are provided in Figures 9 to 13. More detailed tabulated results are provided in Appendix 1.



Output	m3/yr
Inflow from Primary Pond	37,452
Inflow from Pond Rainfall	1,441
Outflow from Recycling	20,212
Outflow from Irrigation	17,261
Outflow from Pond Evaporation	1,180
Outflow from Overtopping	270

Figure 9 WatBal analysis setup screen showing the inputs, pond configuration graphics, average annual storage pond water balance, and monthly storage volume and irrigation depth graphs.



Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
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ET	132	93	79	51	40	31	29	30	30	39	44	84	682
Drainage	1	1	0	0	0	0	0	0	0	1	1	2	6

Figure 10 Average monthly effluent irrigation area (paddock) water balance.

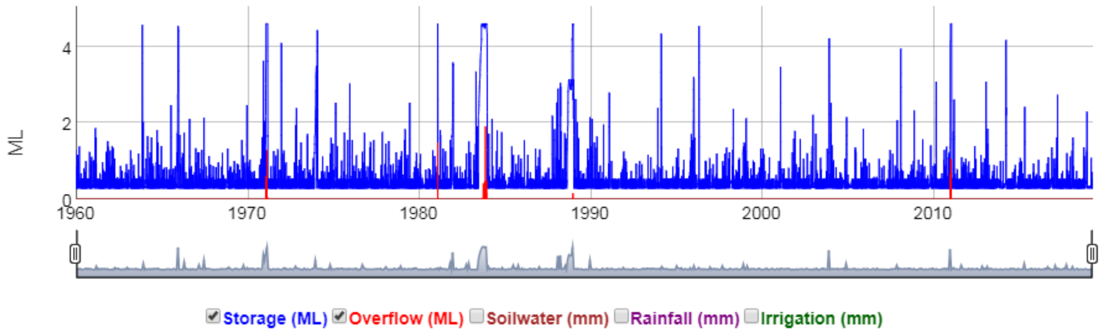

Figure 11 Time series graph showing the predicted storage pond and overflow (spill) volumes from 1960 to present (March 2019).

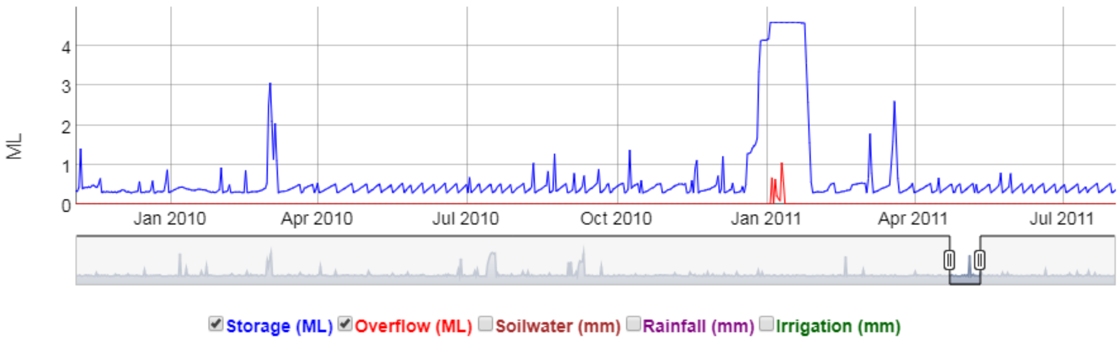

Figure 12 Time series graphs showing predicted storage volume and pond overflows for the period from Nov 2009 to Jul 2011 (incorporating a significant spill event).

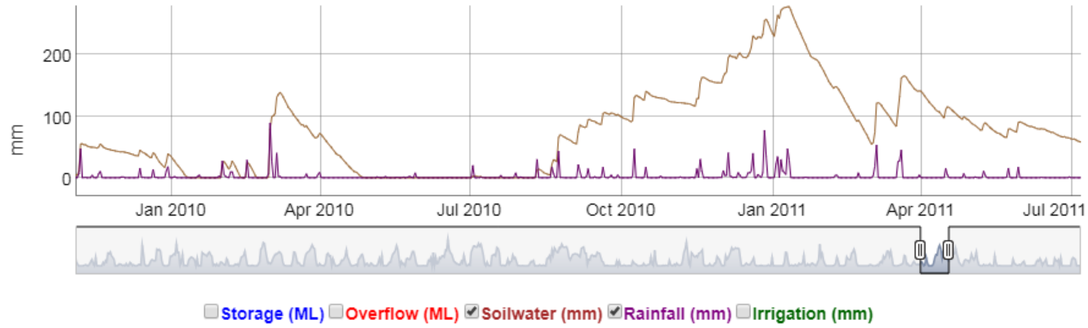

Figure 13 Time series graphs showing soil water and rainfall, for the period from Nov 2009 to Jul 2011.

6. Discussion

The results demonstrate that the new *WatBal* model can be used to effectively and conveniently carry out daily water balance analyses for piggery effluent management systems. It has several advantages over previous models, including:

- Ready access across Australia and internationally by logging in to a custom-made website
- Seamless and prompt selection and importation of relevant climatic data
- Ability to run analyses over extended time periods, from 1900 to the present (119 years currently)
- Builds on existing, widely accepted models, such as *HowLeaky*, providing more rigorous soil water balance and cropping simulations in the effluent irrigation area and a wider, more readily expandable range of crop/pasture species and soil types
- More comprehensive graphical outputs
- Enhanced administrative and user support features.

7. Implications & Recommendations

The *WatBal* model described in this report, is a relatively simple, widely-accessible daily water balance model, developed specifically for modelling Australian piggeries. It is anticipated that it will assist individual producers negotiating planning approvals for new and expanding piggeries in addition to supporting the expansion and consolidation of the pork industry across Australia. The user-friendly, web-based format of the new model will assist consultants involved in preparing proposals for new developments and the regulatory officers who are responsible for assessing the resulting development approval applications. Ultimately, nearby landholders and the general public will be more confident that new piggery developments have been designed to minimise the risk of excessive spillage of effluent storage ponds contaminating the environment. This will in turn enhance the environmental and marketing credentials of the Australian pork industry.

It is recommended that the *WatBal* model be made readily available for use across the industry so that the potential benefits can be fully realised.

8. Intellectual Property

No commercially significant intellectual property is expected to arise from this project. Subject to APL approval, it is anticipated that the *WatBal* model developed by this project will be made freely available for use by producers, consultants, regulators, researchers and industry service providers, to maximise benefits to the industry and wider community.

9. Technical Summary

The calculator is available at: https://watbal.australianpork.com.au/

A tutorial for how to use the WatBal calculator is available at: https://watbal.australianpork.com.au/About/Tutorial

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11. Publications Arising

No publications have arisen from this project to date.

Appendix 1 – Detailed pdf printout

Primary and Storage Pond design 1000 sows farrow to finish example (10894 SPUs) at Porky Pie . Growing Summer reduced till C (40ha) on Average heavy clay PAWC 230 at DALBY POST OFFICE (Generated: 23/04/2019 12:07 PM)

1. Analysis Setup

Name 1000 sows farrow to finish example	Farm Porky Pie
Setup Primary & Storage	Location DALBY POST OFFICE
Soil type Average heavy clay PAWC 230	Crop type Summer reduced till C
Years 1960 to present	Notes

2. Pond Catchment

Concrete catchment 2,500 m2	Earth catchment	1,000 m2
Hard catchment 8,000 m2	Grass (veg) catchment	4,000 m2
Roof catchment 400 m2		

3. Flushing System

Flushing shed SPUs 2,134 SPU	Flushing interval	1 days/flush
Fresh water flushing vol 0 L/flush	Recycled effluent flushing vol	19,000 L/flush
Hosing interval 7 days	Hosing volume	35,000 L/hosing

4. Pull Plug

Pull plug shed SPUs 8,760 SPU	Release interval	14 days/release
Fresh water recharge vol 0 L/recharge	Recycled effluent recharge vol	532,000 L/recharge
Hosing interval 7 days	Hosing volume	63,000 L/hosing

5. Static Pit

Static pit shed SPUs 0 SPU	Release interval	14 days/release
Fresh water recharge vol 0 L/recharge	Recycled effluent recharge vol	0 L/recharge
Hosing interval 1 days	Hosing volume	0 L/hosing

6. Solids Management

Total solids (TS) from sheds 3,500 kg TS/day	Volatile solids (VS) from sheds	2,800 kg VS/day
Solids separation Static rundown screen		

7a. Primary Pond

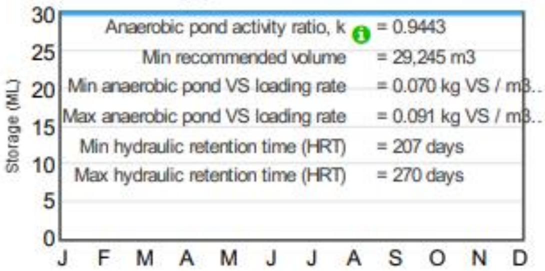
Pond design philosophy	Conventional 'large'	Desludging interval	5 years
Total pond volume	30,000 m3	Pond storage depth	5 m
Batter - lengthwise	1 (V) : 2.5(H)	Batter - breadthwise	1 (V) : 2.5(H)
Length (at embankment crest)	120 m	Freeboard	0.6 m
Cover anchorage allowance	0 m		

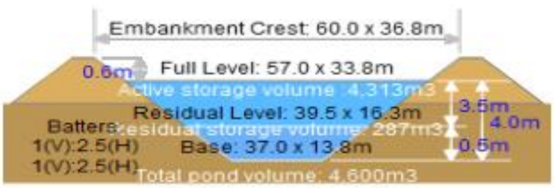
7b. Storage Pond

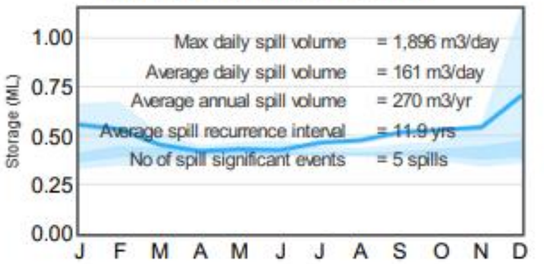
Total storage capacity	4,600 m3	Total storage depth 4 m
Residual storage depth	0.5 m	Length (at embankment crest) 60 m
Batter - lengthwise	1 (V) : 2.5(H)	Batter - breadthwise 1 (V) : 2.5(H)
Freeboard	0.6 m	

8. Effluent Irrigation

Irrig method Low Press Travelling	Effluent irrig area 40 ha
Pump capacity 1 ML/day	Rain to cancel irrig 10 mm
Effluent dilution (shandying) 50 %	Irrigation triggers 25,25,25,25,25,25,25,25,25,25,25,25 mm

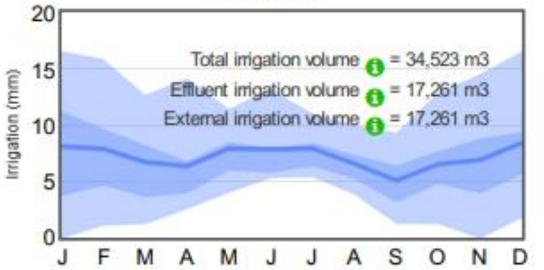


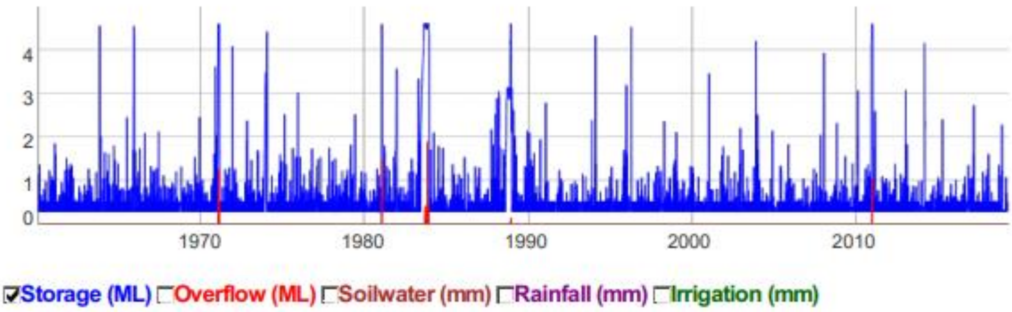




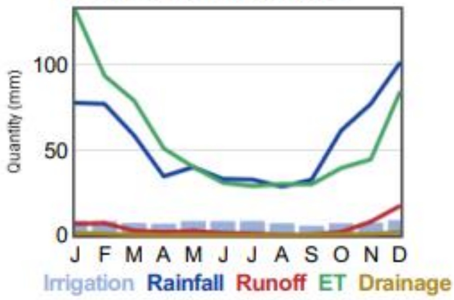
Storage Pond Water balance

Output	m3/yr
Inflow from Primary Pond	37,452
Inflow from Pond Rainfall	1,441
Outflow from Recycling	20,212
Outflow from Irrigation	17,261
Outflow from Pond Evaporation	1,180
Outflow from Overtopping	270





Paddock Summary



Key time-series outputs

Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Irrig(Total)	8	8	7	6	8	8	8	7	5	7	7	8	8
Irrig(Pond)	4	4	3	3	4	4	4	3	3	3	3	4	4
Irrig(Clean)	4	4	3	3	4	4	4	3	3	3	3	4	4
Rainfall	78	77	58	34	40	33	33	29	33	61	77	101	6
Runoff	7	7	3	2	2	1	1	0	1	2	8	17	5
ET	132	93	79	51	40	31	29	30	30	39	44	84	6
Drainage	1	1	0	0	0	0	0	0	0	1	1	2	6

Farm Detailed Outputs

Pig Population

Pig population	10894 SPU
Drinking water calculations	
Live weight / SPU	40 kg/SPU
Feed ingested	2 kg/SPU/day
Wf	2.5
Tf	1.2
Water intake	5 L/SPU/day
Piggery drinking water intake	52,367 L/day
Drinking water wastage	25 %
Drinking water wastage (total)	13,092 L/day
Drinking water wastage	4,781,798 L/yr
Manure production	
Total solids (TS) from sheds	3,500 kg TS/day
Volatile solids (VS) from sheds	2,800 kg VS/day
Standard NEGP estimate of TS discharged from sheds	3,221 kg TS/day
Standard NEGP estimate of VS discharged from sheds	2,684 kg VS/day
Adopted TS discharged from sheds	3,500 kg TS/day
Adopted VS discharged from sheds	2,800 kg VS/day
Manure (faeces + urine) moisture content	87 %
Estimated total manure production	26,923 kg/day
Total manure density	990 kg/m3
Raw manure volume collected in effluent system	27,195 L/day
Raw manure volume collected in effluent system	9,933 m3/yr
Drinking water wastage	
Estimated water intake	52,367 L/day
Typical drinking water wastage rate	25 %
Estimated drinking water wastage volume	13,092 L/day
Total drinking water supplied per day	65,459 L/day
Total drinking water supplied per year	24 ML/yr
Shed effluent management system	
Flushing shed SPUs	2134 SPU
Pull plug shed SPUs	8760 SPU
Static pit shed SPUs	0 SPU
Total SPUs (Total)	10,894 SPU
Flushing interval	1.0 days/flush
Release interval	14 days/release

Release interval	14 days/release
Fresh water flushing vol	0.0 L/flush
Recycled effluent flushing vol	19,000 L/flush
Fresh water recharge vol	0 L/recharge
Fresh water recharge vol	0 L/recharge
Recycled effluent recharge vol	532,000 L/recharge
Recycled effluent recharge vol	0 L/recharge
Total max recycled effluent use per day (flushing sheds) (Flushing)	19,000 L/day
Total max recycled effluent use per day (pull plug) (Pull Plug)	38,000 L/day
Total max recycled effluent use per day (static pit sheds) (Static pit)	0 L/day
Total max recycled effluent use per day (total) (Total)	57,000 L/day
Raw manure volume per flush/release (flushing sheds) (Flushing)	5,327 L/flush-release
Raw manure volume per flush/release (pull plug sheds) (Pull Plug)	306,150 L/flush-release
Raw manure volume per flush/release (static pit sheds) (Static pit)	0 L/flush-release
Raw manure volume (flushing sheds) (Flushing)	5,327 L/day
Raw manure volume (pull plug sheds) (Pull Plug)	21,868 L/day
Raw manure volume (static pit sheds) (Static pit)	0 L/day
Raw manure volume (total) (Total)	27,195 L/day
Flush/recharge volume per day (flushing sheds) (Flushing)	19,000 L/day
Flush/recharge volume per day (pull plug sheds) (Pull Plug)	38,000 L/day
Flush/recharge volume per day (static pit sheds) (Static pit)	0 L/day
Hosing interval	7 days
Hosing interval	7 days
Hosing interval	1 days
Hosing volume	35,000 L/hosing
Hosing volume	63,000 L/hosing
Hosing volume	0 L/hosing
Hosing volume per day (flushing sheds) (Flushing)	5,000 L/day
Hosing volume per day (pull plug sheds) (Pull Plug)	9,000 L/day
Hosing volume per day (static pit sheds) (Static pit)	0 L/day
Hosing volume per day (total) (Total)	14,000 L/day
Drinking water wastage (flushing sheds) (Flushing)	2,565 L/day
Drinking water wastage (pull plug sheds) (Pull Plug)	10,527 L/day
Drinking water wastage (static pit sheds) (Static pit)	0 L/day
Drinking water wastage (Total)	13,092 L/day
Total shed effluent per day (flushing sheds) (Flushing)	31,892 L/day
Total shed effluent per day (pull plug sheds) (Pull Plug)	79,395 L/day
Total shed effluent per day (static pit sheds) (Static pit)	0 L/day

Total shed effluent per day (total) (Total)	111,287 L/day
Total shed effluent per year (flushing sheds) (Flushing)	11,648 m3/yr
Total shed effluent per year (pull plug sheds) (Pull Plug)	28,999 m3/yr
Total shed effluent per year (static pit sheds) (Static pit)	0 m3/yr
Total shed effluent per year (total) (Total)	40,648 L/day
TS concentration (flushing sheds) (Flushing)	2 %
TS concentration (pull plug sheds) (Pull Plug)	4 %
TS concentration (static pit sheds) (Static pit)	NaN %
TS concentration (total) (Total)	3 %
Runoff into effluent system	
Concrete catchment	2,500 m2
Earth catchment	1,000 m2
Hard catchment	8,000 m2
Grass (veg) catchment	4,000 m2
Roof catchment	400 m2
USDA NCRS runoff model CN - ARC I (Concrete)	98
USDA NCRS runoff model CN - ARC II (Concrete)	98
USDA NCRS runoff model CN - ARC III (Concrete)	98
USDA NCRS runoff model CN - ARC I (Earth)	92
USDA NCRS runoff model CN - ARC II (Earth)	93
USDA NCRS runoff model CN - ARC III (Earth)	95
USDA NCRS runoff model CN - ARC I (Hard)	96
USDA NCRS runoff model CN - ARC II (Hard)	96
USDA NCRS runoff model CN - ARC III (Hard)	96
USDA NCRS runoff model CN - ARC I (Grass)	58
USDA NCRS runoff model CN - ARC II (Grass)	76
USDA NCRS runoff model CN - ARC III (Grass)	89
USDA NCRS runoff model CN - ARC I (Roof)	98
USDA NCRS runoff model CN - ARC II (Roof)	98
USDA NCRS runoff model CN - ARC III (Roof)	98
Av annual runoff (concrete) (Concrete)	1,111 m3/yr
Av annual runoff (concrete) (Concrete)	444 mm/yr
% rainfall yield from concrete catchment (Concrete)	68 %
Av annual runoff (earth) (Earth)	243 m3/yr
Av annual runoff (earth) (Earth)	243 mm/yr
% rainfall yield from earth catchment (Earth)	37 %
Av annual runoff (hard) (Hard)	2,721 m3/yr
Av annual runoff (hard) (Hard)	340 mm/yr
% rainfall yield from hard catchment (Hard)	52 %

Av annual runoff (grass) (Grass)	144 m3/yr
Av annual runoff (grass) (Grass)	36 mm/yr
% rainfall yield from grass catchment (Grass)	6 %
Av annual runoff (roof) (Roof)	178 m3/yr
Av annual runoff (roof) (Roof)	444 mm/yr
% rainfall yield from roof catchment (Roof)	68 %
Effluent pre-treatment / solids separation	
Solids separation	Static rundown screen
Total Solids (TS) removal	0 %
Volatile Solids (VS) removal	0 %
TS removal (Other)	28 %
VS removal (Other)	32 %

Primary Pond Detailed Outputs

Pond loading	
Total Solids (TS) pond loading	2,800 kg TS/day
Volatile Solids (VS) pond loading	2,100 kg VS/day
Anaerobic treatment pond	
Anaerobic pond activity ratio, k	0.9443
Pond design philosophy	Conventional 'large'
Suggested max baseline VS loading rate	0.100 kg VS / m3 / day
Suggested adjusted max VS loading rate	0.094 kg VS / m3 / day
Min active treatment vol (VS loading)	22,239 m3
Suggested minimum hydraulic retention time (HRT)	30 days
Effluent volume discharged to pond	111 m3/day
Min active treatment vol (HRT)	3,339 m3
Min active treatment vol (VS and HRT)	22,239 m3
Sludge storage	
Sludge accumulation rate	
Desludging interval	5.0 years
Sludge storage volume	7,005 m3
Suggested total pond vol	29,245 m3
Total pond volume	30,000 m3
Active treatment volume	22,995 m3
Min anaerobic pond VS loading rate	0.070 kg VS / m3 / day
Max anaerobic pond VS loading rate	0.091 kg VS / m3 / day
Min hydraulic retention time (HRT)	207 days
Max hydraulic retention time (HRT)	270 days

Pond dimensions	
Pond storage depth	5.00 m
Batter - lengthwise	1 (V) : 2.5(H)
Batter - breadthwise	1 (V) : 2.5(H)
Freeboard	0.60 m
Length (at embankment crest)	120.0 m
Length (at full storage level)	117 m
Breadth (at full storage level)	69 m
Breadth (at embankment crest)	72 m
Length (at base)	92 m
Breadth (at base)	44 m
Sludge Depth Cubic Param A	8
Sludge Depth Cubic Param B	341
Sludge Depth Cubic Param C	4,086
Sludge Depth Cubic Param D	-7,005
Max sludge depth	2 m
Length (at max sludge depth)	100 m
Breadth (at max sludge depth)	52 m
Min depth to top of sludge - below full storage level	3 m
Cover anchorage allowance	0.0 m
Cover length	120 m
Cover breadth	73 m
Cover area - trenched into bank	8,735 m2
Max baseline VS loading rate before crusting	0.400 kg VS/m3/day
Dam factor (kdam = Pond evap / ETo)	1.05

Average annual primary pond water balance (m3/yr)		
Inflow Runoff	4,397 m3/yr	
Inflow Manure	9,933 m3/yr	
Inflow Hosing/Flushing		30,715 m3/yr
Rainfall		5,677 m3/yr
Evaporation		13,270 m3/yr
Outflows		37,452 m3/yr
Average annual inflow volume		50,722 m3/yr
Max daily outflow volume		3,267 m3/day
Min daily outflow volume		0 m3/day
Average daily outflow volume		103 m3/day
Average annual outflow volume		37,452 m3/yr

Storage Pond Detailed Outputs	
Pond dimensions	
Total storage capacity	4,600 m3
Initial volume	2,300 ML
Total storage depth	4.0 m
Residual storage depth	0.50 m
Batter - lengthwise	1 (V) : 2.5(H)
Batter - breadthwise	1 (V) : 2.5(H)
Freeboard	0.60 m
Length (at embankment crest)	60 m
Full storage level (Length)	57 m
Full storage level (Breadth)	34 m
Embankment crest (Breadth)	37 m
Base (Length)	37 m
Base (Breadth)	14 m
Top of residual storage (Length)	40 m
Top of residual storage (Breadth)	16 m
Active storage volume, Va	4,313 ML
Residual storage volume, Vr	287 ML
Dam factor (kdam = Pond evap / ETo)	1

Effluent dilution (shandying	
Effluent dilution (shandying)	50 %

Pond spills (overflow elements)	
Max daily spill volume	1,896 m3/day
Min daily spill volume	0 m3/day
Average daily spill volume	161 m3/day
Average annual spill volume	270 m3/yr
Total number of spill days	99 days
Average spill days per year	2 days/yr
No of spill significant events	5 spills
Average spill recurrence interval	11.9 yrs

Average annual storage pond water balance (m3/yr)	
Inflows	37,452 m3/yr
Rainfall	1,441 m3/yr
Evaporation	1,180 m3/yr
Recycling	20,212 m3/yr
Irrigation	17,261 m3/yr
Outflows	270 m3/yr

Top Spill Events

Period	**Amount (m3)**	**Length (days)**
06 Sep 1983 to 11 Dec 1983	6,448	97
04 Feb 1971 to 09 Mar 1971	3,926	34
03 Jan 2011 to 21 Jan 2011	3,480	19
07 Feb 1981 to 08 Feb 1981	1,914	2
19 Dec 1988 to 27 Dec 1988	219	9