water e-journal
Online Journal of the Australian Water Association
ISSN 2206-1991
Volume 1 No 4 2016
https://doi.org/10.21139/wej.2016.043

MAXIMISING SEWERAGE ASSET DATA: A DESKTOP TOOL TO RANK SEWAGE PUMPING PERFORMANCE

A DATA-DRIVEN DECISION MAKING TOOL TO MONITOR SA WATER'S CRITICAL SEWERAGE INFRASTRUCTURE

F Bressan, S Zhong, N Turich

ABSTRACT

In the past, the identification of wastewater assets – particularly Wastewater Treatment Plants (WWTP) and Sewage Pump Stations (SPS) – for capacity upgrades was a mix of local knowledge and experience.

The new mega-data era stimulated the innovative idea of using existing data sources to produce a priority list of SPSs that require an upgrade due to reaching their capacity. This lead to the development of an Automated sewage Discharge Analysis Tool (ADAT).

ADAT measures the relationship between pump duties and theoretical catchment discharges as an indicator of capacity performance of these systems. ADAT enables a relatively quick process to estimate how SPS sub-catchments are behaving. Figure 1 is an example of a recent SPS upgrade – an ideal candidate to have been identified through the ADAT process.

Now in its second year in operation, ADAT has ranked almost 500 of SA Water's SPS sub-catchments belonging to 24 WWTP areas, producing data that is reportable in both tabular and graphical form, ADAT can generate these results to a suburb level as well.

It was also realised through the development of this automated process, sewage discharge results at the WWTP level could also be examined against water consumption rates. This provided a theoretical method to determine catchments likely to be susceptible to infiltration effects.

As a result the business has readily available information to (theoretically) identify where sewage connection growth has or is soon to exceed pump station capacity. This data can then help supplement planning decisions by SA Water's Assets team, leading to a more targeted approach on the asset renewal and growth program for SPSs.

INTRODUCTION

The South Australian Water Corporation (SA Water) operates more than 500 Sewage Pump Stations (SPS) servicing a catchment area of around 800 km^2.

Figure 1. One of SA Water's sewage pump stations recently upgraded

Generally, operational deficiencies have led the way for SPS upgrade projects. While this factor will still be taken into account, SA Water's Treatment and Network Planning (TNP) team set themselves a challenge to develop a prioritisation tool that would rank each of its SPSs in terms of its capacity. In this case, capacity would be evaluated by trending sewage connection growth against SPS pumping performance criteria.

Using a mix of Geographical Information System (GIS) data, Microsoft Excel macro-based tools and pump station asset performance records, SA Water's TNP team has developed a simple tool to rank SPS performance. This is using existing and future connection growth derived from sewage discharge rates against theoretical SPS pump duties. From this desktop assessment tool a readily available business intelligence platform was created that has the capability to identify likely SPS upgrade candidates.

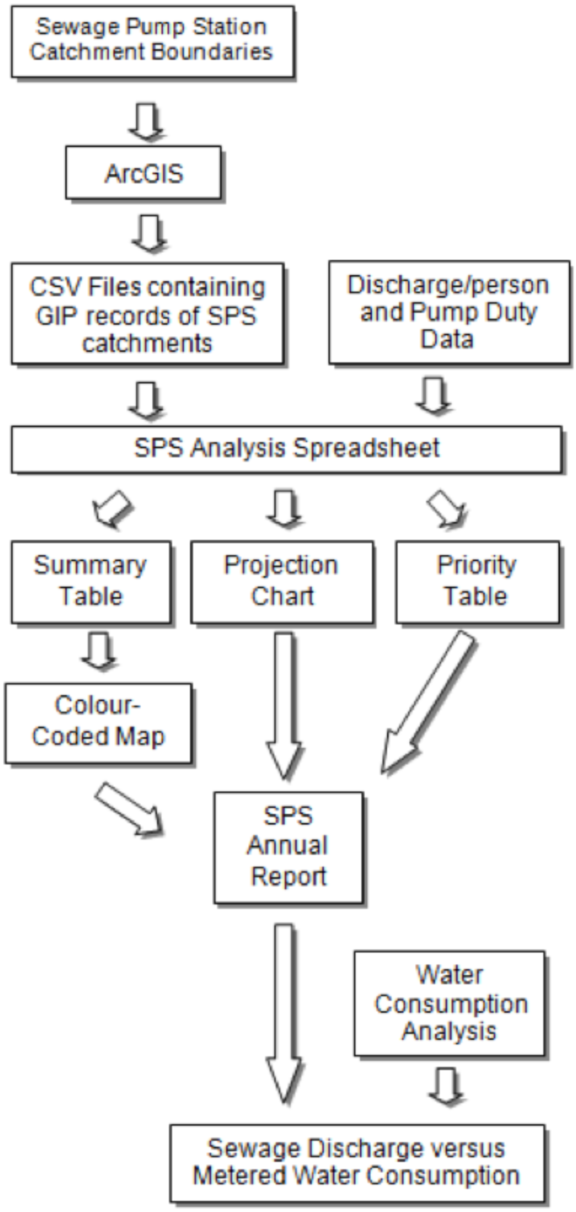

Figure 2. Flow chart of the key inputs to ADAT

SEWAGE CATCHMENT DISCHARGE ANALYSIS – AN INSIGHT ON HOW THE AUTOMATED PROCESS WORKS

Process

SA Water's TNP team has developed a Microsoft Excel-based macro that analyses sewage catchment discharges by interrogating both ArcGIS sewage connection data (Government Inspection Points (GIPs) as termed by SA Water) and Microsoft Excel sewage pump duty records. Figure 2 illustrates the various data inputs and how they are used in ADAT.

Step One - Spatial Analysis

The spatial analysis has been conducted using the ArcGIS database platform to extract the required attribute data for each of the SPS catchment areas.

To achieve this, a new ArcGIS polygon layer was created that captured all of the pumping station boundaries. This is possible through the running of an internally-developed ArcMap tool that traces the pipes upstream of the pump station and then automatically draws a buffer zone around the identified catchment pipes.

A unique catchment identifier (or ID) is then assigned to each catchment in addition to a brief description of the pumping station label, street name and the name of the specific WWTP the catchment discharges nto.

Once this new catchment layer has been created, an automated "iterative" tool was used to extract GIP information for each of the catchment polygons that also includes a count of the total GIPs together with their respective connection dates.

As this tool was developed using the ArcGIS Toolbox environment, it can be easily accessed and modified by other users if required.

Considering this tool was applied to all of SA Water's catchments across the state, there were more than 500 Comma-Separated Value (CSV) output files generated through this process.

As a quality check to verify the catchment boundaries have been correctly identified, corresponding maps were also created for each of the pumping catchments using the in-built data-driven page function as coded in the Python programming language. A map example is shown in Figure 3, highlighting the sewage main configuration and the locations of the residential connections (or GIPs). The data-driven map has the ability to display the catchment boundary, the sewage main configuration, the locations of the residential connections (or GIPs) and any non-residential connections to the network (the latter is not present in this case)

Step Two - Discharge Analysis

Having collected the required GIP information from ArcGIS, the spreadsheet capabilities of the Excel program were used to develop flow projection charts. The discharge analysis spreadsheet was used to analyse historic connection counts in order to produce average connection increases per year. Using these average annual growth rates, they were then applied to generate a 25-year growth projection plot for each of the SPS catchments.

This spreadsheet also takes into account other source documents, including the WWTP annual records and the Pumping Station Index records. Both these data sources also use the Microsoft Excel spreadsheet platform and so could be read seamlessly for discharge and pumping information. ADAT uses the discharge information to convert the GIP count into an equivalent population, develop an average discharge rate per (equivalent) person per day and eventually to produce a mean daily peak flow rate as well as a maximum (or wet-weather equivalent) peak (in litres per second) – equations adopted in the spreadsheet macro include the basic hydraulic equations shown below:

Figure 3. A typical data-driven map

$$\frac{daily\ sewage\ volume\ (ML)}{number\ of\ connections} x$$

(1)

$$Q_t = \frac{EP \times f \times DWF}{24 \times 60 \times 60} + TW$$

$$occupancy\ rate\ =\ dry\ weather\ flow$$

(2)

where

Q = sewer flow rate (L/s)

EP = Equivalent population upstream of the sewer main

DWF = Dry weather flow (L/EP/day)

f_i = Peaking factors with respect to DWF

Mean Daily Peak Flow Factor (f_1)

(f_1) = 6.172 x EP $^{(-0.1067)}$

Maximum Peak Flow Factor (f_2)

(f_2) = 14.1 x EP $^{(-0.142)}$

TW = Licensed trade waste flow

Conversely, the design pump duty for each pumping catchment is read from SA Water's Pumping Station Index records. The design pump duty is typically sourced from engineering design calculations for each SPS. This design duty is then recorded as the limiting capacity threshold.

It is plotted against the mean daily peak flow projections, creating a simple visual display to show if and when the sewage catchment flow will reach the SPS capacity.

Using Microsoft Excel macro programming, a single batch process is run to generate sewage flow projection charts and their corresponding summary tables for every pumping catchment.

An example of this output is shown in Figure 4. Producing this data, particularly in tabular form, enables the outputs to be ranked based on the year the pumping capacity has been estimated to be reached.

Step Three – Publishing Outputs

ADAT generated more than 1,000 figures, consisting of maps, tables and charts.

Catchment	[Sewage Pump Station Name]				
STP	[Sewage Treatment Plant Name]	**Total Number of GIPs within the STP Catchment Area**	29887		
People / Allotment (GIP)	2.5	**Discharge (Litre) / GIP / Day**	767	**% of STP GIPs**	2.6%
Discharge (Litre) / Person / Day	307	**Pump Duty (L/sec)**	21.5	**Year at Capacity**	2030
Catchment Area (m^2)	786032	**Total Length of Gravity Main (m)**	10065		

	Year	**Total GIP**	**GIP Growth (Abs)**	**GIP Growth (%)**	**Equivalent Population**	**Q_{ave} (L/sec)**	**Q_{peak} (L/sec)**	**Q_{max} (L/sec)**
Historic	2006	701	-	-	1753	6.22	17.30	27.69
	2007	701	0	0.0%	1753	6.22	17.30	27.69
	2008	706	5	0.7%	1765	6.27	17.42	27.86
	2009	714	8	1.1%	1785	6.34	17.59	28.15
	2010	734	20	2.7%	1835	6.51	18.03	28.85
	2011	742	8	1.1%	1855	6.58	18.21	29.13
	2012	750	8	1.1%	1875	6.66	18.38	29.41
	2013	756	6	0.8%	1890	6.71	18.51	29.62
	2014	768	12	1.6%	1920	6.82	18.78	30.04
Current	**2015**	**773**	**5**	**0.6%**	**1933**	**6.86**	**18.88**	**30.21**
25-Year Projection (based on 3yr rolling avg)	2016	782	9	1.1%	1954	6.94	19.07	30.51
	2017	790	9	1.1%	1975	7.01	19.25	30.81
	2018	799	9	1.1%	1996	7.09	19.44	31.10
	2019	807	9	1.1%	2018	7.16	19.62	31.40
	2020	816	9	1.0%	2039	7.24	19.81	31.69
	2021	824	9	1.0%	2060	7.31	19.99	31.99
	2022	833	9	1.0%	2081	7.39	20.18	32.28
	2023	841	9	1.0%	2103	7.46	20.36	32.58
	2024	850	9	1.0%	2124	7.54	20.55	32.87
	2025	858	9	1.0%	2145	7.61	20.73	33.17
	2026	867	9	1.0%	2166	7.69	20.91	33.46
	2027	875	9	1.0%	2188	7.76	21.10	33.75
	2028	884	9	1.0%	2209	7.84	21.28	34.05
	2029	892	9	1.0%	2230	7.92	21.46	34.34
	2030	901	9	0.9%	2251	7.99	21.64	34.63
	2031	909	9	0.9%	2273	8.07	21.83	34.92
	2032	918	9	0.9%	2294	8.14	22.01	35.21
	2033	926	9	0.9%	2315	8.22	22.19	35.50
	2034	935	9	0.9%	2336	8.29	22.37	35.80
	2035	943	9	0.9%	2358	8.37	22.55	36.09
	2036	952	9	0.9%	2379	8.44	22.74	36.38
	2037	960	9	0.9%	2400	8.52	22.92	36.67
	2038	969	9	0.9%	2421	8.59	23.10	36.96
	2039	977	9	0.9%	2443	8.67	23.28	37.25
	2040	986	9	0.9%	2464	8.75	23.46	37.54

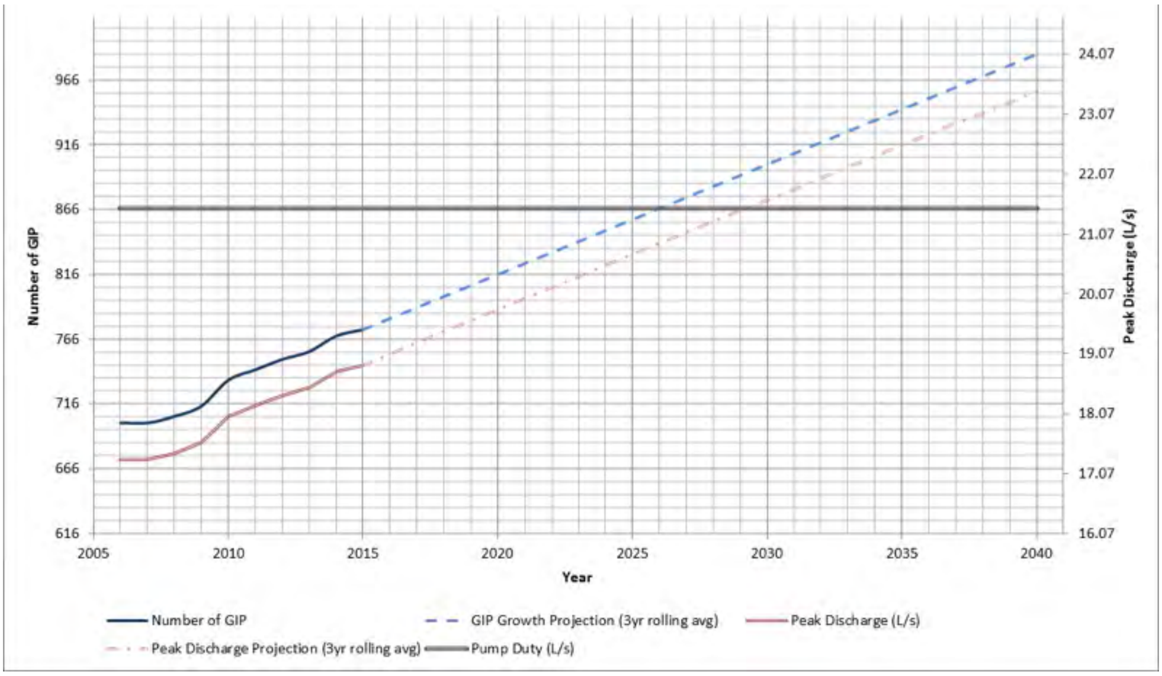

Figure 4. Example of the output generated from ADAT

This then triggered a need to develop a Microsoft Word-based macro code to compile these figures into a single report that displays the outputs in a standard and universal form.

For ease of locating a particular pumping catchment, the display sequence has been sorted in alphabetical order.

Each pumping catchment section contains a locality map, summary table and a growth projection chart. Once completed, the report is uploaded to SA Water's internal document sharing platform to allow stakeholders to access the information.

When the batch run has been completed, these results are exported back into the ArcGIS system to produce colour-coded mapping of the pumping catchments. This mapping can also be extended to include "heat maps", which have the ability to provide a simple visual cue to where capacity has or will shortly be reached.

An example of the report and "heat-map" produced by the automated discharge analysis tool is shown as Figure 5.

Step Four – Comparison Between Water Consumption and Sewage Discharge

The analytics applied to metered water consumption and sewage discharges enabled the TNP team to compare a simple water and sewage balance at a STP level. Limited to the metropolitan STPs, the total water consumption and sewage discharge volumes were compared to provide a theoretical method of measuring the proportion of drinking water discharged back into the sewerage system.

The key steps in developing the water consumption, sewage discharge and rainfall comparison are shown in Figure 6.

OUTCOMES

ADAT has been able to produce tabular and graphic representations of historic and projected sewage discharges for each individual pump sub-catchment (where information exists).

ADAT has provided SA Water with a simple and effective way to identify SPS sub-catchments that have reached their theoretical design pump duty (1-pump mode) and those that are estimated to be reached sometime over the next 25 years or beyond.

The key outcome of ADAT is the development of a prioritisation tool that has ranked every SPS catchment into four distinct categories:

1. SPS catchments with existing design flows ≥ theoretical pump capacity
2. SPS catchments with future design flows expected to occur within the next 25 years ≥ theoretical pump capacity
3. SPS catchments with future design flows expected to occur beyond the next 25 years < theoretical pump capacity
4. SPS catchments with missing theoretical pump capacities.

In 2013-14 the four categories were calculated as eight per cent, five per cent, 70 per cent and 16 per cent, respectively.

Further to establishing sewage flows it was an ideal progression to have these flows compared against water consumption equivalents.

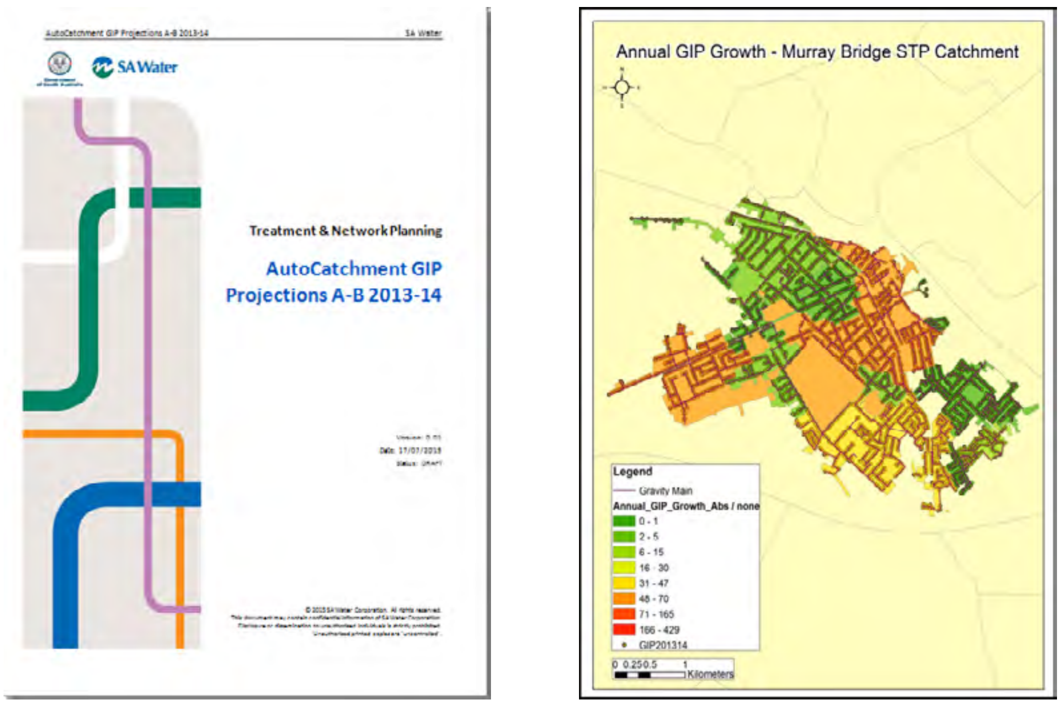

Figure 5. Published outputs – summary report and heat map

Through spatial means the volumes of water consumption and sewage discharge on an annual basis both within and across catchment areas were quantified. This produced the ratio of consumption to discharge.

Displaying annual water consumption and sewage discharge volumes with rainfall data provided a simple indicator of catchment behaviour. Figure 7 displays the three components of water consumption, sewage discharges and rainfall on an annual basis across SA Water's major metropolitan WWTPs.

In 2013-14, it was calculated that the metropolitan area returned three-quarters of metered water consumption to the sewer (this sewage return rate ratio is within typical ranges applied in the industry and a commonly applied value when specific return rates are not available).

The ratio differed for the individual WWTPs, enabling identification of catchments with higher levels of infiltration.

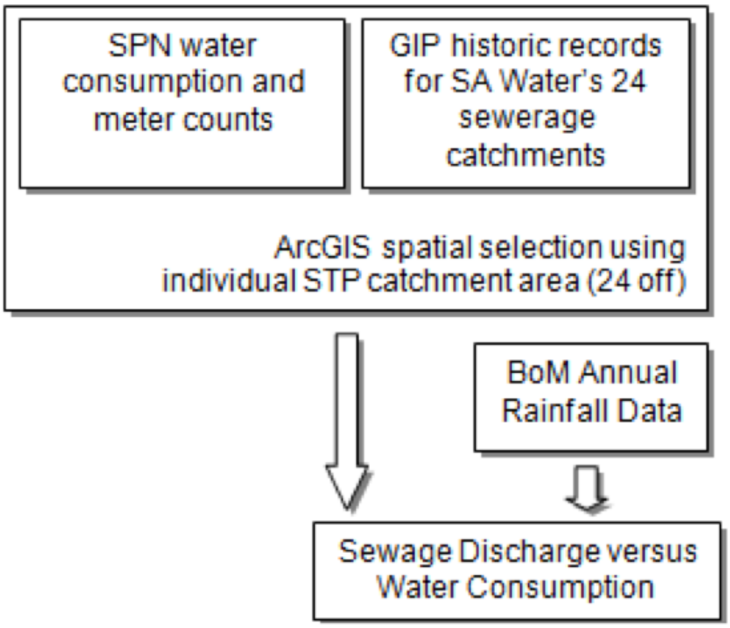

Figure 6. Key inputs to sewage discharge to water consumption comparison

BENEFITS AND OPPORTUNITIES

Through the development of ADAT, there have been several benefits discovered which have included:

- identifying data gaps in SPS pump duty records,
- a relatively quick and inexpensive process to identify sewage pump stations running at or close to their theoretical limits

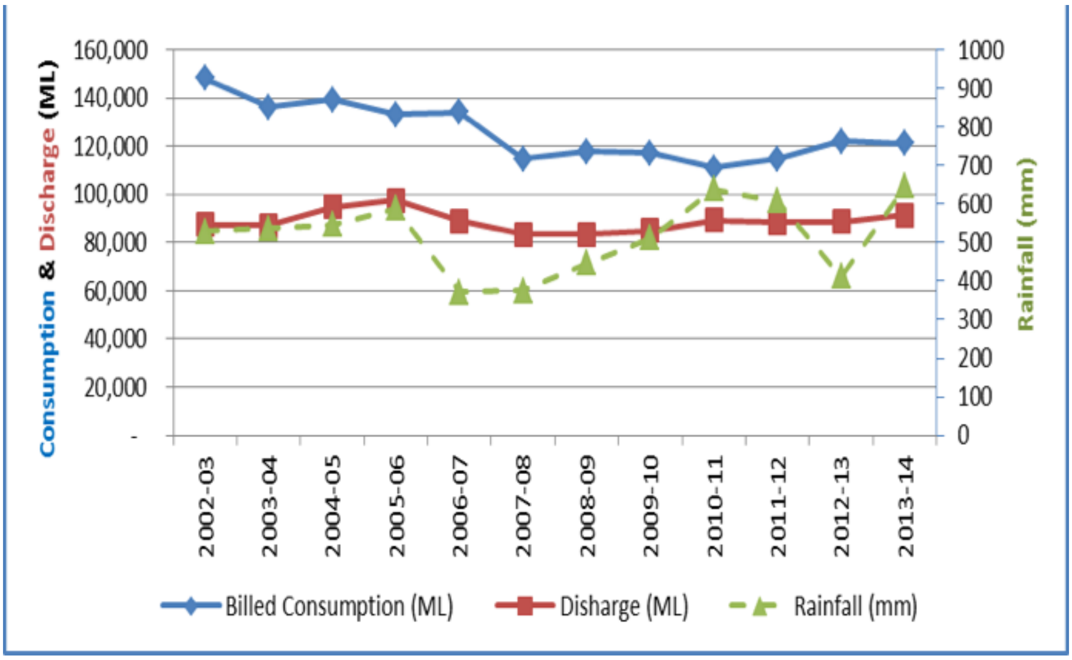

Figure 7. Historic plot of annual water consumption, sewage discharges and rainfall

- a simple means of comparing industry-supplied planning projections against actual sewage connection growth rates,
- a method to verify anectodal operational information,
- a method to compare metered water consumption with sewage discharge rates, and
- an ability to generate a broad understanding of growth statistics at different spatial scales; at WWTP, SPS and suburb levels.

Several opportunities to further improve ADAT have also been identified. These include:

- extending ADAT to consider twwo-pump operating conditions,
- including Septic Treatment Effluent Discharge Scheme (STEDs or also now known as Community Wastewater Management Systems) connections, which are not presently accounted for,
- analyses of data at smaller time scales would allow measurement of the impact of higher and lower rainfall years on the sewage return rate ratio,
- where recycled water systems exist, extending the return to sewer ratio by introducing recycled water volumes from a particular catchment. The intent is to provide an improved understanding of the influence of rainfall and or groundwater infiltration on volumes and, where applicable, quality,
- investigation of the impact of water restrictions and water efficient rebates on the discharge rates and trends.

CONCLUSION

In the past, local knowledge and experience identified problem SPS areas, which were centred largely on anecdotal information. SA Water's TNP team has developed ADAT, which allows the ranking of SPS in terms of their pump duty performance against estimated dry weather peak inflows.

Using data analytics to capture historic sewage connection growth and translating this into dry weather peak inflows, SA Water has the ability to compare this inflow against theoretical SPS pump capacity limits for more than 500 of its sewage pumping catchments.

Ranking these, in terms of sewage flow capacities, is now possible. In addition ranking is also possible on WWTP catchments that are more susceptible to infiltration.

Other benefits of ADAT include identification of a small number of pump duty data gaps. Additionally, an improved understanding has now been gained of actual connection growth statistics being experienced, both at the individual SPS sub-catchment and suburb level.

ADAT has provided a planning platform that can be applied during the capital planning phases in addition to providing SA Water an insight into customer discharge behaviour.

It also better informs the business on any asset investment strategy by seeking out areas growing at a faster rate than others – through the derivation of the catchment growth "heat maps" – and targeting these areas for further investigation.

Through the development of ADAT, the TNP team has gathered business intelligence in a relatively simple process and has avoided a highly repetitive manual task. ADAT's strength is that it applies a systematic approach in analysing every sewer pump stations through a single batch run.

ACKNOWLEDGMENT

The authors would like to acknowledge the specialist knowledge from Stephen Bologiannis (Engineer), Patrick Hayde (Water Manager) and XJ Wang (Prinicipal Engineer) from the SA Water TNP team.

THE AUTHORS

Flavio Bressan, Manager Wastewater, has over 25 years' experience in the engineering sector, with over 15 years of them within the water industry.

He had spent almost 20 years in the private sector on a variety of civil and water related projects before joining SA Water.

Shane Zhong, Graduate Engineer, has developed valuable insights into data analytics during his stint in SA Water's TNP team.

He has used this knowledge by developing smart data-driven analysis tools across both the water and wastewater areas of the business. Shane's keen interest in this field has led him to study for a Graduate Diploma of Data Science at Monash University.

Nick Turich, Manager Connections, has had extensive experience in the areas of planning and projections work across the water, sewage and recycled water sectors over his past seven years as the Senior Planner in the TNP team. He is now managing the Connections team in SA Water.

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