DISCUSSION

JOURNAL OF THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING
ISSN 1021-2019
Vol 60 No 1, March 2018, Pages 56–57, Paper 1200

Publishing particulars of the paper under discussion

Vol 59 (1) 2017, Pages 11–21, Paper 1200: Planning for desalination in the context of the Western Cape water supply system

(http://dx.doi.org/10.17159/2309-8775/2017/v59n1a2)

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COMMENT

The authors must be congratulated on demonstrating the introduction of a seawater desalination plant as an integral part of a water supply system – in this case the Western Cape water supply system. While this new resource would provide a constant and reliable source of water, its operating costs typically are high in comparison with the cost of other traditional resource developments. As the authors showed (e.g. in Figure 7 of their paper), due to the stochastic nature of the hydrology on which the traditional resources depend, the augmentation requirement from a desalination plant with its high operating cost will be of a stochastic nature as well. This follows as the annual operating decisions, based on system risk analyses, can be expected to favour resources with lower operating costs in times when the system is relatively flush and the risk of curtailments in the short term is expected to be within acceptable limits. The authors therefore demonstrated that, by simulating the annual operating decisions according to the methodology proposed by Van Niekerk and Du Plessis (quoted reference 2013a), the operating costs would also vary stochastically over time. These variable costs then carry over into the determination of the unit reference values (URVs), showing the latter themselves to be uncertain in nature.

It is with the authors' calculation of the URVs that this writer has a difficulty. While seemingly the improved URV determination methodology by Van Niekerk and Du Plessis (referenced incorrectly as 2013a – it should have been quoted as 2013b) is accepted by the authors (2017:14), the equation for determining the URV in their Equation 1 (2017:15) is not the same as Equation 2 by Van Niekerk and Du Plessis (quoted ref 2013b:552), which is:

$$\text{URV} = \frac{\textit{PV of life cycle costs}}{\textit{PV of quantity of water incrementally assured}}$$

In the authors' Equation 1 the denominator is given as "NPV of the water supplied from the desalination plant (W_n)", which is quite different to the "PV of quantity of water incrementally assured" in the above equation.

Van Niekerk (2013) demonstrated that the URV concept should be grounded in the cost-effectiveness analysis (CEA) theory. Van Niekerk and Du Plessis summarised it as follows (quoted 2013b:554): "Examination of the URV measure in view of its underlying CEA economic theory revealed that a good measure of effectiveness would be the incremental water availability assured by the expansion of a system and bounded by the projected demand curve until full capacity is reached. The PV of the annual quantities of water thus assured is used as denominator in the URV equation."

Analogous to what was advocated by Van Niekerk and Du Plessis for inter-basin transfer systems, a conceptual separation is required between the water supplied by the desalination plant, affecting operating costs, and the water incrementally assured, used as a proxy measure for effectiveness.

The authors did not make such a separation. It is suggested that the URV calculations be redone with the denominator amended in accordance with the methodology of Van Niekerk and Du Plessis (quoted 2013b). The expectation is that the URV results will be quite different,

Blersch CL, Du Plessis JA. Planning for desalination in the context of the Western Cape water supply.
J. S. Afr. Inst. Civ. Eng. 2018:60(1), Art. #1200, 2 pages. http://dx.doi.org/10.17159/2309-8775/2018/v60n1a6

be revelatory regarding the optimality of desalination plants in terms of sizing and operations, and give rise to some different conclusions from those arrived at in the paper.

The difference in URV calculations can be illustrated by taking the example of the 150 Mℓ/d desalination plant with the 70% storage level trigger (scenario D (70%)). The incremental 1:50 year yield of this plant is about 120 Mℓ/d (44.10^6 m^3/a) (estimated from Figure 5), providing about two to three years of augmented supply before a follow-up intervention is required (deduced from Table 3), and the median (50 percentile) supply over the 20 years (from Figure 6) is estimated as 72 Mℓ/d on average. The denominator in this case should be the incrementally assured supply over the economic life of the intervention (assumed here to be 20 years to fit in roughly with the planning horizon). While the discounted volume of water, used as denominator to determine the URV of R15.49/m^3 in Figure 4, was not stated in the paper, logically it had to relate to the 72 Mℓ/d figure, whereas it should have been associated with the 120 Mℓ/d, being the approximate incremental assurance provided by the desalination plant, in keeping with the approach by Van Niekerk and Du Plessis. The correct median URV for the 150 Mℓ/d plant, operated at a 70% trigger level, would be closer to an estimated R9.30/m^3 than the quoted R15.49/m^3.

A further note for correction: The title at the top, within the border, of Figure 5, referring to historic firm yield, has presumably been incorrectly copied from Figure 4. It should refer to the 1 in 50 year yield, as in the title given below the border for Figure 5.

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References

Blersch, C L & Du Plessis, J A 2017. Planning for desalination in the context of the Western Cape water supply system. *Journal of the South African Institution of Civil Engineering*, 59(1): 11–21.

Van Niekerk, P H 2013. Hydrologic-economic appraisal of inter-basin water transfer projects. PhD thesis, Stellenbosch University. URL: **http://hdl.handle.net/10019.1/79887**.

RESPONSE FROM AUTHORS

Dr Peter van Niekerk has raised a distinction between the denominator used in the equation for calculation of Unit Reference Values (URVs) in the paper (Equation 1) and that used in the work of Van Niekerk and Du Plessis which was the reference point for this equation. Dr Van Niekerk explained that the value that should be used according to his methodology is associated with the volume of water incrementally assured. With reference to our paper, this value would be the present value of the incremental water availability assured by the expansion of the system, being the 1:50 year yield calculated using the equations shown on Figure 5 or using Equation 3, bounded by the projected demand curve depicted in Figure 2. On the other hand, the value used in the denominator of the URV equation to calculate URVs (as shown in Table 4 of our paper) is the present value of the annual volume of water supplied over the 20-year horizon. For example, the 50^{th} percentile URV values in Table 4 were calculated using the present value of the 50^{th} percentile supply values over the 20-year period as presented in Figure 6.

On reviewing Dr Van Niekerk's explanation, he is correct that there is indeed a distinction between the values used in the two papers (and that they might yield different results). However, we do not believe that the approach adopted in our paper is incorrect, and is still of value. Updating the results using the volume of water incrementally assured for comparison could be the subject of further research. For now, we propose that the third and fourth sentences of the second paragraph under "Cost estimation and calculation of URVs" on page 14 be amended to read "The URV approach, as presented by Hoffman and Du Plessis (2008), was adapted by Van Niekerk and Du Plessis (2013a) by using the actual volume of water supplied based on a stochastic analysis in the WRPM to calculate the operating costs in the nominator, and the volume of water incrementally assured by the project in the denominator, to calculate the URVs of inter-basin transfers. This approach was adapted for application in this paper by, instead, using the modelled annual volumes of water supplied from the desalination plant, as extracted from the WRPM analyses, to calculate costs."

In addition, with reference to Equation 1, it was in fact the Present Value (PV) of costs that was used in the calculations, not the Net Present Value (NPV) as was stated in the paper.

Lastly, the correction regarding Figure 5 is noted. This title should read "Increase in 1 in 50 year yield".

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DR VAN NIEKERK'S COMMENT TO AUTHORS' RESPONSE

The URV approach of Van Niekerk and Du Plessis was solidly grounded in the economic theory of cost-effectiveness analysis. The departure by Blersch and Du Plessis, as is suggested in their proposed amendment, is neither motivated, substantiated, nor grounded in economic theory.

Both approaches cannot be correct. An erroneous application of the URV methodology leads to fundamentally flawed results. Blersch and Du Plessis's conclusions are based on such results. I consider their paper as important for the insights that it can bring in considering the inclusion of a desalination plant in a water resource system. I would therefore urge the authors to urgently apply the necessary corrections.

AUTHORS' FURTHER RESPONSE

While we agree with the URV approach suggested in Van Niekerk and Du Plessis, we do not agree that the deviation as used in the authors' (Blersch and Du Plessis) publication resulted in *fundamentally flawed* results based on the *objectives of the paper*. As stated in our original response, we agree that it will be interesting (and needed) to repeat the exercise with the approach (with reference to the using of the volume of water incrementally assured), but in this case study we raised a number of limitations which might have impacted on the final results presented in the paper. It was, however, the *stochastic nature* of the volume of water that was supplied (or assured) that was of importance to illustrate, as was done in the paper.

It is, however, doubtful that the main findings (that the unit reference values for the desalination plant decrease as the percentage supply from the plant increases, and that the unit reference values decrease with an increase in desalination plant capacity) will change, given that the volume of water incrementally assured, based on our analysis, varies with desalination plant trigger level in a similar way to the actual volume of water supplied.