04 August 2017

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Michael Spencer, CEO
Water Stewardship Australia Limited
PO Box 184
East Melbourne
Victoria 8002

By email: michael@waterstewardship.org.au

Water Research Laboratory

Dear Michael,

Task 1 - WRA Gaps Analysis and Recommendations

The Water Research Laboratory (WRL) at the School of Civil and Environmental Engineering at UNSW, Sydney has been commissioned to provide an independent peer review of a Water Resource Assessment (WRA) Report for the Nestle Thailand Ayutthaya Factory in accordance with Alliance for Water Stewardship (AWS) Standards provided by Water Stewardship Australia (WSA). The terms of reference for the review are reproduced in Section 1.

The report provided to WRL for review was "*Groundwater Modeling at PVT Factory in Ayutthaya Province*" dated 26 June 2014 by HydroGeoSci Co. Ltd. (2014). The rationale provided for modelling was to assist Nestle select a new location for a deep groundwater well for their Perrier Vittel Thailand (PVT) factory based on quality, quantity and sustainability of groundwater resources within the factory area. The stated objective of the modelling exercise is reported to be an assessment of the sustainability of the Nonthaburi (NB) and Thon Buri (TB) aquifers in which Well Numbers 2, 3, 4 and 5 are located. Sustainability was defined as a 50-year period from present day.

1. Scope of Works

Review of the existing WRA report, documentation of any gaps in relation to the relevant AWS Standards / Criteria and provision of recommendations on how any gaps in the requirements may be fulfilled. AWS Standards that recommendations would be provided against include 2.1, 2.1.2, 2.1.4, 2.3.3, 2.3.4, 2.6.1, 2.7.1, 2.7.2 and 2.10.1. This would include information / data required, format of information / data and possible sources to obtain information / data.

2. Materials Reviewed

In undertaking this review, WRL was instructed to consider the following primary documents:

1. 1401_Final Report.pdf - "*Groundwater Modelling at the PVT Factory in Ayutthaya Province – Final Report*" by Hydrogeosci Co., Ltd; provided on 13 July 2017; and
2. CRP 2.0 AY June 2016 - Final version-updated Nov.xlsx – a community relations process spreadsheet provided on 26 July 2017.

The following documents were also provided on commissioning and briefly inspected but were not reviewed in detail:

- ayutthaya_map.pdf;
- Chao Phraya River Basin.docx – A short summary of the regional hydrology; and
- TH_Water_Management_Strategy_2015-2026_translate.pdf – this document has formatting issues and many parts are illegible.

The following document was provided for review on 31 July 2017 following provision of preliminary review feedback:

- TH_Water_Management_Strategy_2015-2026 – A Government Water Management Strategy Document in Thai; and
- WRR Action plan - TH 2014 - Updated 5.7.2015.pdf - A 5 July 2015 audit of a Water Resources Review – Action Plan dated May 16-17, 2014.

The scope of works for this peer review report was consideration of a groundwater modelling report dated 26 June 2014 and a stakeholder analysis dated June 2016. The review of these documents was completed as per the scope of works.

3. Summary Comments

Some significant work has been undertaken over the last three years to characterise the locations of key aquifers and aquitards and some aspects of the site hydro-geochemistry that might threaten future water security at the PVT Factory (salinity). There has also been some considerable community outreach involving data collection, data analysis, meetings and stewardship to work towards better protection of surface and groundwater resources.

The materials provided for review included a community relations process study and number of preliminary modelling predictions from 2014. No outputs from the community relations process action-plan or a water resources assessment report were provided for review. The provided modelling predictions explored, at a simple level, how the groundwater system might respond to future pumping which could be used to support future planning and economic decision making. The authors are to be congratulated for this work.

Our review of the modelling report and community relations process spreadsheet from 2014 identifies opportunities for improvements against AWS requirements 2.1, 2.1.2, 2.1.4, 2.3.3, 2.3.4, 2.6.1, 2.7.1, 2.7.2 and 2.10.1. Our independent technical assessment of the modelling report also identifies a number of gaps in the groundwater modelling and the water resource sustainability recommendations provided by HydroGeoSci Co. Ltd. (2014) that could well be explained in the water resources report still in preparation.

Gaps in the information provided for review included:

- Important information on the PVT Factory site data and the hydrogeological and hydrogeochemical analyses completed to date;
- Full details of the PVT groundwater model setup, model configuration, scenarios, simulation outputs, sensitivity testing and uncertainty analysis that are required for independent verification of the approach to the study and the model findings;
- Provision of previous modelling and data analysis reports that are mentioned by HydroGeoSci Co. Ltd. (2014) in support of the site conceptual model, study approach and findings;

- Important information on the surrounding land uses, current and potential future groundwater quality concerns and future water use requirements;
- Very limited discussion of site water risks and opportunities, future water resources scenarios and water-related challenges in the catchment; and
- Discussion of data analyses and model outputs in the context of future water management.

4. Structure of this Peer Review Report

This peer review report is summarised as follows:

- Section 5: Groundwater Modelling Report
- Section 6: Community Relations Process
- Section 7: Water Resources Review Audit
- Section 8: Completion of Water Resource Assessment

Technical commentary on modelling, reporting gaps and recommendations to provide improvements to meet the AWS Standards are provided in Section 5 of this letter. Section 6 summarises the water related aspects of the community relations process to identify potential gaps against the AWS standards. Section 7 provides some notes and recommendations from our brief consideration of the Water Resources Review Audit document. Section 8 provides preliminary recommendations for preparing a Water Resource Assessment that conforms with the AWS Standards.

5. Modelling Report

This section of the peer review addresses:

1. Geological and Chemical Characterisation
2. Hydrogeological Characterisation
3. Modelling Details and Outputs
4. AWS Standards Checklist

Summary comments and recommendations against each of these items are provided in Sections 4.1 to 4.3 below. More specific comments, questions and data / information requests on these topics are provided in Table 1.

5.1 Geological and Chemical Characterisation

To improve the utility of the geological and hydrogeochemical mapping work for Nestle, WRL recommends that the report be updated to provide:

a) Groundwater levels and contours on figures 2.4, 2.5 and 2.7 to provide hydrogeological context;

b) References to the third-party documents and calculations that were relied upon to support the chosen model boundaries and dispersivity values;

c) Details of how the geological mapping work was interpreted in three dimensions across the study area (i.e. the conceptual model), including an estimation of uncertainties related to the interpretation and implications for the forward model predictions;

d) Details of land-use and potential contaminants in the capture zone of Wells 2, 3, 4 and 5 which may have implications for human health, water pre-treatment and groundwater end-use;

e) Data that justify introducing a point contaminant source of chloride at PW55698 of 700 mg/L on (we assume) day 0 (1 January 2010) of the numerical model simulation;

f) An assessment of existing wells in the capture zone that may be leaking poor quality water from the BK and PD aquifers into the NL, NB, SK, PT and TB aquifers and simulation of possible impacts from these wells in the numerical model;

g) Consider conducting water quality sampling and detailed water quality screening analysis at all wells screened in or below the NB aquifer within the capture zone of Well No. 2 to predict future water quality at Well No. 2. The analytes for laboratory analysis should be determined based upon the history of the surrounding land use. Besides inorganic major ions, analytes might also include heavy metals, organochlorides, pesticides, E-Coli, coliforms or any other contaminants of potential concern that might not be readily removed from the groundwater with treatment.

5.2 Hydrogeological Characterisation

WRL recommends that:

a) The report be updated to include presentations and hydrogeological analyses of field chemistry and hydraulic test data from the site to establish data-based estimates of recharge, hydraulic conductivity, specific storage and specific yield. For example, the report does not describe any pumping test or chloride mass balance analyses to determine the properties of aquifers and aquitards or the recharge to the aquifer;

b) Hydraulic conductivity values of 10^{-5} to 10^{-6} m/d for clay are very low. Details of these low permeability sediments should be described and laboratory and/or field evidence should be provided to support the chosen values;

5.3 Modelling Details and Outputs

WRL recommends that all details of the modelling workflow should be reported, including:

1. Method of calibration;
2. Tables (and maps if required) of all model settings, boundary conditions and parameters;
3. Justifications for the chosen model parameters, boundary conditions, grid size, number of model layers and settings including time step, convergence criteria and accuracy;
4. Model validation to 30-50% of the measured data, to demonstrate model calibration;
5. Details of the parameters adjusted to achieve model calibration;
6. A statistical measure of the error between model prediction and observation;
7. Details of any model settings that were different between calibration and prediction;
8. Predictions of initial heads and 50-year drawdowns in the BK, PD and NL aquifer;
9. Discussion of the confined / unconfined status of the aquifer now and in the future;
10. The directions of groundwater flow now and in the future;
11. Results of all sensitivity tests; and
12. Influence of uncertainty in chosen recharge, specific storage and hydraulic conductivity parameters and future land use scenarios on the 50-year predictions;
13. Any additional details required by local legislation, regulation and guidelines.

Table 1: Additional questions

Item #	Report Section / Figure	Questions / Comments
1	Figure 2.14	Please identify the process(es) responsible for causing pulses of elevated chloride and increasing trend in Well No. 2 since 2010. How significant an issue is this for production into the future?

2	Figure 2.15, 2.16	What caused the decreases on chloride over time since 2012 at Well no 3 and 4?
7	Figure 3-9 to Figure 3-13	the model does not appear to reproduce the fluctuation of chloride concentration. Please discuss the model limitation and confidence in the results.
8	Figure 3.10	Why does the model over predict aquifer head at Well 3 and 4 by about 10m between 300 and 800 days but fit almost perfectly at other times? E.g. are you missing a source of pumping in the aquifer, is recharge constant rather than variable through time?
15	General comment	What are the implications on prediction / management if PW55698 is plugged? Are there any other problem wells nearby PVT that might cause problems for the deeper, fresher aquifers that Nestle wish to use for the next 50 years?
16	General comment	The model predicts significant declines to groundwater levels over time. Are the pumps currently installed to a depth to accommodate these declines? What are the implications of these declines on future pumping costs to Nestle and other nearby users? Is the abstraction sustainable?
17	General comment	The model appears slightly biased towards over-predicting chloride concentrations. Future revisions to the modelling workflow should attempt to eliminate this bias with improved boundary conditions and least-squares, calibration optimisation workflows.
20	General comment	Based on the results in Appendix VI, the prediction doesn't look right – the head prediction are oscillating a lot at the beginning (1500 days) then it drops slowly. What is your level of confidence in the model prediction? Please verify and discuss the prediction in more detail.

5.4 AWS Standards Checklist

A summary table providing WRL comments addressing the AWS standards are presented in Table 2.

Table 2: AWS Standards – Section 2.1, 2.1.2, 2.1.4, 2.3.3, 2.3.4, 2.6.1, 2.7.1, 2.7.2 and 2.10.1

Item	AWS Indicators	Core / Points / Comments
2.1 Define the physical scope: Identify the site's operational boundaries, the sources the site draws its water from, the locations where the site returns its discharge to, and the catchment(s) that the site affect(s) and is reliant upon.		
2.1.1	Documentation or map of the site's boundaries	a) Please document how the model extents were selected. b) Please justify the chosen model extents with reference to the hydrology and hydrogeology of the region and the confined / unconfined nature of the aquifer. c) Please document the values and the physical basis for the values (heads and hydraulic conductivity) used at the boundary of the groundwater flow model. d) Please explain how the model boundaries might change over the next 50 years.

Item	AWS Indicators	Core / Points / Comments
2.1.2	Names and location of water sources, including both water service provider (if applicable) and ultimate source water	a) Please provide some information on the two rivers (Lop Buri River and Pa-Sak River) included in the model (i.e. variation in flow, stage heights, and its connectivity with aquifer system). b) Please describe how this information was represented, or calibrated to, within the groundwater model.
2.1.4	Geographical description or map of the catchment(s)	a) Please provide a section describing the rainfall in the region (i.e. annual rainfall, monthly rainfall, quantity of rain during dry/wet season…). b) Please provide information on the extent and properties of the catchment area. c) Please provide information on estimation of the evapotranspiration in the model area. d) Please provide details and mapping of the current and historical land use within the likely capture zone of the groundwater pumping wells and potential range of groundwater contaminants introduced into the soil and groundwater from those activities. e) Please classify the stakeholder groundwater wells in the likely capture zone of the PVT groundwater pumping wells with respect to land use and risks as described in (d) above.

2.3 Gather water-related data for the catchment: Gather credible and temporally relevant data from the catchment:

- Water governance, including catchment plan(s), water-related public policies, major publicly led initiatives under way, relevant goals, and all water-related legal, regulatory requirements;
- Water balance for all sources while considering future supply and demand trends;
- Water quality for all sources while considering future physical, chemical and biological quality trends;
- Important Water-Related Areas, including their identification and current status, while considering future trends;
- Infrastructure's current status and exposure to extreme events while considering expected future needs.

Item	AWS Indicators	Core / Points / Comments
2.3.3	Catchment water balance by temporally relevant time unit and commentary on future supply and demand trends	a) Please provide detailed calculation or time-series of each inflow and outflow in Table 3-2 of the report. b) Please describe the water governance, including catchment plan(s), water-related public policies, major publicly led initiatives under way, relevant goals, and all water-related legal, regulatory requirements that may impact future groundwater and surface water use. c) Please describe important water-related areas in the potential capture zone of the PVT water supply wells or in the recharge zone of the NB and TB aquifers. This should include existing or planned groundwater supply works and any ecosystems in groundwater discharge zones that might be influenced by pumping at PVT Factory. d) Please describe the infrastructure status of the PVT pumping wells, year of construction and design life. e) Please describe the response of the aquifer systems to extreme weather events including drought, flood and climate change and describe how this might impact the sustainability of the resource into the future. f) Please describe the PVT water supply demand trend and/or scenarios for the PVT Factory water requirements for the next 50 years. g) Please describe the likely groundwater and surface water demand trend for other water uses in model domain for the next 50 years. h) Please provide the future surface water and groundwater balance for each scenario.
2.3.4	Appropriate and credibly measured data to represent the physical, chemical and biological status of the site's water source(s) by temporally relevant time unit, and commentary on any anticipated future changes in water quality	a) No information on biological or contaminant groundwater quality is provided. Information on major ions is limited to tabular presentations of the data. Please provide details of all available data and all hydrogeochemical analyses of this data. b) See comment 2.1.4(d) above. c) Please describe the likely land use trends in the capture zone of the PVT pumping wells and how it may affect recharge water quality for the next 50 years. d) Please describe the likely changes in surface water and groundwater quality in the capture zone of the PVT wells for the next 50 years. e) Please document the water quality samples and field and laboratory data analyses that should be collected into the future. In Australia there are a number of national and state guidelines for designing water quality monitoring, sampling, analysis and management. This includes the National Water Quality Management Strategy. Alternatively, the EU Water Framework could be considered.
2.6 Understand shared water-related challenges in the catchment: Based upon the status of the catchment and stakeholder input, identify and prioritize the shared water-related challenges that affect the site and that affect the social, environmental and/or economic status of the catchment(s). In considering the challenges, the drivers of future trends and how these issues are currently being addressed by public-sector agencies must all be noted.		

Item	AWS Indicators	Core / Points / Comments
2.6.1	Prioritized and justified list of shared water challenges that also considers drivers and notes related to public-sector agency efforts	a) Please provide this information. b) See comments in 2.3.3 and 2.3.4 above. c) Please discuss the implications of extremes scenarios (e.g. Dry/Wet years), model sensitivity to other users pumping rates and security of water supply given potential changes to groundwater and surface water demands from other users.
2.7 Understand and prioritize the site's water risks and opportunities: Based upon the status of the site, existing risk management plans and/or the issues identified in 2.6, assess and prioritize the water risks and opportunities affecting the site.		
2.7.1	Prioritized list of water risks facing the site, noting severity of impact and likelihood within a given time frame	a) Insufficient background information has been provided at this time. To enable more detailed comment, please provide any existing assessments and further background information (see above comments). b) There is a petrol station nearby, potentially in the groundwater capture zone of the PVT Factory. No information is provided on the history, the status of the underground storage tanks or the quality of groundwater surrounding this site. Has the risk of this site to the PVT water supply been assessed? c) Note that the integrity of at least one groundwater work (well) near the PVT Factory is allowing lower quality, possibly contaminated, groundwater to move downwards from the BK and PD aquifers compromising the quality of the groundwater in the NB aquifer. There may be other wells with similar issues. In the short term this will continue to degrade the quality of water arriving at Well No. 2. In the long term it may compromise water quality in the deeper aquifers.
2.7.2	Prioritized list of water-related opportunities for the site	a) Insufficient background information has been provided at this time. To enable more detailed comment, please provide any existing assessments and further background information (see above comments).
2.7.3	Estimate of potential savings/value creation	a) Insufficient background information has been provided at this time. To enable more detailed comment, please provide any existing assessments and further background information (see above comments).
2.10 Review a formal study on future water resources scenarios: Gather detailed information that explores water usability (quantity and quality) under future scenarios (including extreme events, population and urbanization changes, economic development, possible climate change impact scenarios, and anticipated infrastructure needs) within the catchment and comment on the scenarios' impacts upon the site's growth strategy.		

Item	AWS Indicators	Core / Points / Comments
2.10.1	Copy of a study that details projected future state conditions relative to current quantity and quality parameters and a comment on potential impacts upon the site's growth strategy	a) Insufficient background information has been provided at this time. To enable more detailed comment, please provide any existing assessments and further background information (see above comments).

6. Stakeholder Analysis Summary and Review

The community engagement spreadsheet dated June 2016 provides information and an analysis of stakeholder concerns and expectations. Some reporting on this process and all the outcomes of the action plan would help address AWS Standards 2.1, 2.3, 2.6 and 2.7. Specifically, WRL recommends further identification and discussion of:

- The apparent contradictions between statements concerning water availability;
- The reasons for the groundwater odours and the yellow film / sediments in groundwater;
- The chemicals that would contaminate groundwater during flooding;
- Uncontrollable private wells and work to estimate their potential groundwater usage which may be a significant source of uncertainty in the groundwater modelling predictions;
- An assessment of potential future groundwater use by stakeholders due to growth, climate change and farming and variability in consumption due to seasonality, flood and drought.
- A map of the region showing property boundaries, land use (e.g. farms, factories, fuel stations), groundwater wells, rivers, streams and stakeholders in the capture zone and drawdown zone of the PVT Factory; and
- Plan view maps of the individual BK, PD, NL, NB, SK, PT and TB aquifers showing current and projected future groundwater use at each pumping well.
- A pie chart, bar chart or table documenting the estimated groundwater usage of all groundwater users in the capture zone and drawdown zone of the PVT Factory; and
- A pie chart, bar chart or table documenting the estimated groundwater usage of the stakeholders that were consulted during the community engagement study.

Stakeholder response analysis suggests that the most pressing water issues in the region are the local Municipalities ability to supply drinking water, followed by unwillingness of potential sources of contamination to change their practices, then water shortages and NW's expansion projects. This helps to highlight some of the region's shared water challenges (AWS Standard 2.6), however, further information on water data (AWS Standard 2.3) needs to be presented to fully understand these challenges and to prioritize the site's water risks and opportunities (AWS Standard 2.7).

In general, the community engagement process demonstrates good stewardship of the water resources by the PVT Factory. Specifically, the document identifies twelve (12) measures that were completed since community engagement in 2014 to address local issues. This included provisioning drinking water for locals, gathering more surface and groundwater quality data and undertaking engagement activities that will improve groundwater quality by reducing the risks of groundwater contamination from off-site land use activities. Presentation and analysis of this data would help address the AWS Standards.

7. Audit of Water Resources Review – Action Plan

Based upon our inspection of the provided audit document, we provide the following comments on the modelling work that has been completed and additional recommendations for addressing the AWS Standards:

1. Groundwater at the site has elevated temperatures of between 35 and 40 degrees centigrade which will impact the density and hydraulic conductivity values utilised for modelling groundwater flow. The modelling report should document the temperature distribution and temporal variability in the aquifers and describe / demonstrate how significant this is for calibration and prediction.
2. The suspected problem well, PW55698, was reported to be plugged by the Department of Groundwater Resources (DGR) on 21/10/2014. Water taken from this well during plugging had a chloride reading of 2,400 ppm. The modelling report appears to be based upon the assumption of a constant source term of 700 ppm leaking into the aquifer at this point. The modelling report did not document the quantity of water with chloride concentration of 700 ppm leaking into the deep aquifer at this point. Given these reporting gaps and the differences in actual and assumed concentration, some further examination of the validity and conservatism of the previous modelling appears warranted.
3. The audit draws attention to high ammonia levels in raw water. This information needs to be documented to better characterise the groundwater resource quality to comply with the AWS Standards.
4. There is suggestion of some issues with microorganisms at Well #2. Information on microorganisms in the aquifers or the well need to be documented to better characterise the groundwater resource to comply with the AWS Standards.
5. Details of the water mapping and savings measures completed in July 2014 including monthly water usage and losses.
6. It appears that some plans are in place to optimise water usage at the site which is in accordance with the AWS Standards:
    a. "*In the last years, Ayutthaya factory improved significantly its water ratio (1.83 l/l in 2008 down to 1.38 l/l in 2013). Nevertheless, due to the growth in the Market we have to maximize our production's capacity on site. Looking for additional water savings is part of the strategy. It's recommended to develop a detailed water saving action plan (potential saving in absolute value expressed in m^3, timing, responsible, cost, status) in order to deliver the challenging objective of -4% in 2014.*"
    b. The audit reports that on 18/12/2014, "*Water mapping has been developed and utilized for water saving project. Actions have been identified and implemented according to water mapping and trend of water ratio is decreasing*."

    Further details of these plans should be documented to demonstrate compliance with the relevant AWS Standards.

8. Completion of the Water Resource Assessment Report

Based upon the information reviewed, as described above, it appears that Nestle is committed to Water Stewardship at its PVT Factory and that there exists a draft Water Resource Assessment Report dated May 16-17, 2014 that has not been provided for review. It also appears that significant additional work has been undertaken over the last three years including preliminary modelling, field data collection, data analysis and community outreach and education to improve water quality.

The next stage of this peer review calls for a desktop study of available data to identify relevant and readily available information to complete the above gaps in the WRA report to address the AWS

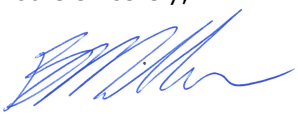
requirements. Before this review is provided, it is recommended that all available information and modelling work held by Nestle be compiled into a single draft Water Resource Assessment Report taking into consideration the peer review commentary provided above and the guidance provided in the AWS Standards.

When complete, the updated WRA report should demonstrate how it addresses each of the key indicators provided in sections 2.1, 2.3, 2.6, 2.7 and 2.10 of the AWS Standards. Further details can be found in the AWS Standards document. We also recommend that any modelling reports presented in support of the Water Resource Assessment be self-assessed against the review check-lists provided by Barnett et al (2012) in the Australian Groundwater Modelling Guidelines. Checklists can be found at Table 2-1 and Table 9-2 of the guidelines.

More specific recommendations on the format and possible sources of data to address the gaps identified in the current reporting may be provided by UNSW upon request. To provide this advice UNSW would require additional context on the site, the future resource needs of PVT Factory and more detail on the investigations completed to date.

Thank you for the opportunity to provide this initial gaps analysis peer review. WRL would be please to provide more detailed comment when an a Water Resource Assessment Report is presented for review. If you have any questions regarding these review comments please contact Mr Doug Anderson (d.anderson@wrl.unsw.edu.au) in the first instance.

Yours sincerely,



for **G P Smith**
Manager