WATER AVAILABILITY AND FOREST LANDUSE PLANNING TOOL. FINAL REPORT. Sept 2007.

Review

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This document is a review and commentary on the new *Water Availability and Forest Landuse Planning Tool* (WAFL) based on the report on its development prepared by Hydro Tasmania Consulting.

The report suffers from not being a comprehensive description of the tool and its purpose, caveats and uses. It should be relegate to the status of a contractual completion report, and a separate communication materials and a manual should be developed.

1. General comments

The basis for the tool

There is a strong need for a planning tool which can assist in quantifying the issue of the impact of change in landuse on water inception and its implications for stream flow, downstream users and environmental assets. Such a planning tool needs to be spatially explicit – i.e. GIS based, and must link available data on catchment drainage, flows, water uses, and environmental assets to changes in vegetation/landuse effects on stream flow in a way that quantifies changes and possible impacts in specific catchments or sub-catchments. It should also be applicable across Tasmania.

This project has developed a tool which satisfies these requirements (with limitations that I explore below), and hence services a substantial need both in terms of quantifying the problem, supporting water and forest management planning and as a basis for developing policy on the issue. DPIW is to be commended on this initiative.

The tool links:

- A set of empirically derived equations which link change in land use from grassland to plantation, and from native forest to plantation, sourced from the CSIRO TasLucas tool; with
- The state's water balance models (AWBM) which model river flows and water use at sub-catchment scales; and
- Spatial data on forestry resources sourced from industry (area and age of plantations, native forest etc); with
- The CFEV river conservation data.

In doing this it allows scenarios of changed forestry land use to be evaluated in terms of their impacts on water yield, patterns of daily flows and impacts on conservation value of rivers at sub-catchment scales, as compared to the current state.

Such a tool should be of substantial use to government and industry for scoping the potential impact of future plantation/forestry development within catchments on water yield, availability and environmental risk for:

- A statewide assessment of the location and extent of the problem;
- Evaluating the relationship between potential landuse and climate change influences on stream flows;
- Individual water management plans;
- Individual regional/district or property forestry plans;
- Planning by water authorities or local government with regard to future water yields and management needs for security and/or environmental protection.

Both the TasLucas equations and the AWBM models pose constraints on the use of the tool (see below), but each represents the first significant phase of development of such tools for the state. The WAFL tool has the advantage of a modular architecture, so new landuse-water yield relationships could be added as they become available. Improvements to the water balance models could also be readily incorporated when needed. Improvements to land use, water abstraction and vegetation data can also be readily incorporated. The tool's further development should be managed in a transparent and scientifically credible way, with changes made on the basis of sound, peer reviewed science and with documented quality assurance.

The tool presents a good opportunity to scope the magnitude and extent of the interception issue, initiating management prescriptions for forestry planning (which have been lacking to date), and kicking off a policy and regulatory debate in government, which has been lacking to date despite considerable public concern.

I am conscious that there is no policy context within which the use of this tool currently rests, other than the Water Management Planning process and, loosely, under the Forest Practices Act. It would appear that development of state policy and regulatory instruments to manage this issue should now be initiated to facilitate management of this issue by government and the private sector.

2. The report

This report is very much an internal process report about how the model works, prepared by the technical team that ran the project. It is short, and its style relates only to people who will further develop or use the model. It lacks a comprehensive description of the rationale, basis and constraints of the tool's utility. There are some components which are not fully described – for example the 'forest groups' input is not explained in the report. Otherwise it appears to satisfy the basic needs of the DPIW Branch involved in tool development.

It should not be circulated to outside groups and stakeholders without a report which comprehensively explains the background, context, aims and options for use and development of the tool, as well as the provenance and current assumptions within model components and existing data sets embedded within it.

3. The tool

I think the approach is conceptually and technically sound, and the general components of the tool link logically together.

There are four main components to the Tool:

- Forestry – streamflow (TasLucas) equations
- Subcatchment water balance (AWBM) models
- Environmental condition (CFEV) data and flow relationships
- Landuse and vegetation age (Forestry, TasVeg) data

I cannot review the technical aspects of each set of these inputs in detail, as it is beyond the scope of this review (and in some aspects, my expertise). However, I do make comments on each as they pertain to the purpose of the WAFL tool.

3.1 Forestry – streamflow equations

There is a variety of methods that can be used to develop relationships between changes in water yield and changes in vegetation cover, age and type. The more sophisticated models are mechanistic or process–based, explaining plant water relationships at small scales and relating these to local soil, subsurface and surface hydrology. They are computationally complex and need large amounts of local data. These data and such calibrated models do not exist for most Tasmanian situations.

The TasLucas project took a 'top down', less complex and more empirical route to this problem. It was not designed to be a fully process based model with detailed empirical information on small scale features and processes. The equations developed for it make predictions based on catchment scale changes in forest land use and streamflow observed in a series of paired catchment studies that were relevant as practicable to forestry land use and rainfalls in Tasmania. These studies investigated the changes of streamflow associated with major forest management changes for periods ranging up to decades.

The TasLucas tool was developed by CSIRO under NRM funding to attempt what the WAFL Tool is doing at the subcatchment scale. The WAFL Tool takes the equations at the heart of TasLucas and links them to DPIW's new set off water balance models which can take other abstractive uses into account. It also adds functionality in the form of outputs related to environmental risks, flow statistics and the ability to adjust rainfall data.

The land use changes summarised in Tas Lucas to develop the equations were grouped into the following three categories:

- grasslands or cropping land converted to plantations,
- native forests converted to plantations,
- native forests were harvested and regenerated.

There were no substantial differences in the water yield relationships for the latter two categories so they were combined. Other land use changes were not included though the approach, and the WAFL tool, could easily be adapted to include them.

Regression relationships were developed between time since land use change and proportional yield change. These are then scaled up by area to assess net change in streamflow at sub-catchment scale. The age of native forest and plantations is a major influence on the water use, so this effect is included in the annual time step.

The restriction of the TasLucas project analysis to published studies adds the benefit of scientific peer review to the genesis of the equations. The catchment studies included afforestation experiments, the conversion of native forests to plantations and the harvesting of native forests and the associated changes in the forest age structure.

The response curves are primarily based on the observed responses in streamflow in the sets of small experimental catchments (7 for conversion of grazing land to plantation, 8 for conversion and/or harvesting of native forest). The resulting response curves (and equations) were internally validated against the calibration studies. None of these studies was based in Tasmania, although, the Glendhu (New Zealand) study had a similar climate and latitude to wetter parts of Tasmania. The overall performance of the relationships was, however, partially externally validated by application of TasLucas to party of the Hellyer catchment in NW Tasmania. Further validation should be conducted for selected gauging stations in Tasmania.

As stated in the TasLucas report, this predictive approach is only robust within specified bounds. Limitations on the scale and precision of modeling are also imposed by:

- Scale of paired catchment studies included in developing the relationships. A minimum 'patch' size of ca. 2 km^2 applies, as does an upper limit of 35 years to the time-flow response curves.
- Lack of small scale spatial information on the distribution of forest operations, coupes etc within study sub-catchments in relation to catchment topography and drainage. This is likely to only be a minor issue when data is aggregated to subcatchment scale, but should be evaluated at some stage.
- Limited knowledge of groundwater-surface water relations. An argument exists that over the longer term, groundwater stores become relatively less important as a driver of surface water change, but this can be problematic at small time steps and local scales. The AWBM models does include a groundwater store component, primarily as a means of fitting to calibration surface gauging data, which in some cases may be from a different catchment and groundwater system. The desire to inspect outputs at annual and more frequent time steps with regard to risks should require an assessment of the need to improve the groundwater-surface water component of the water balance models. Some groundwater systems in Tasmania are highly heterogeneous in spatial layout and temporal response. Those which pose risks to successful AWBM modelling at sub-catchment scales should be identified and improvements in modelling sought where necessary. Recognised hydrological expertise and hydro-geological (e.g. from within Hydro Tasmania and MRT) should be sought to scope areas here this poses a risk to modelling. This may also be of benefit to the use of AWBM models in Water Management Planning.

The relationships are described as simple curves which can be adjusted by adjusting long term mean average rainfall. Their accuracy could be substantially improved by:

- Including upper and lower ('worst estimate') error bounds on the TasLucas curves which could be run (as equations) through the model to generate upper and lower bounds for predictions;

- Adjusting annual time steps in the curves to mean annual rainfall from an input rainfall time series.

Each landuse/vegetation polygon in WAFL is assigned a TasLucas response curve based on the rainfall, current vegetation type, age and rotation for current vegetation conditions. The TasLucas equations do not discriminate between tree types. This should be improved in future as local empirical knowledge of tree-water relations improves (e.g. the work of Sandra Roberts FT). The TasLucas report did show that the species of trees and type of forest (native or plantation) were not a significant factor in determining the water use in the available dataset. I suspect that other errors (in land use mapping, ageing, quantifying abstractions local groundwater-surface water relations) would be substantially greater sources of error at small to intermediate scales than this.

The TasLucas equations do not discriminate between pasture/crop types. There is published evidence that different pastures and crops lead to differing infiltration characteristics and water use. Improved descriptions of these alternative land uses can readily be incorporated into the WAFL model as required, but would need to be accompanied by accurate land use/vegetation mapping (TasVeg is inaccurate at this level of detail).

3.2 Water balance modelling (AWBM)

The models

I can make no detailed comment on the performance of these models, or the accuracy of their storage and loss functions including how they manage groundwater-surface relations. The rationale for the three surface stores and the partial area and capacity of them is not explained in the report, along with the decisions made in fitting parameters for the groundwater store.

The models are deliberately simple, though they are empirically calibrated against real local gauging data, against which they show reasonable levels of precision in total annual flow volumes, and the timing and sequence of flow events, though with variable performance in predicting magnitudes of peak flows and sequences of baseflows, which differ between seasons (e.g. see HEC 2005).

The AWBM models capture information on:

- Current water entitlement allocations in each subcatchment.
- Environmental flow requirements for each subcatchment.
- Daily climate data - approx 5 km x 5 km interpolated gridded rainfall data.

They are run for specific stream drainage sub-catchment 'nodes' and can, if needed, be modeled at a range of different sub-catchment scales. Model performance at small scales would however be limited by:

- Spatial scale of rainfall data and interpolation;
- Accuracy of re-scaling gauging flow data to new locations;
- Lack of knowledge of groundwater-surface water relationships, specifically nature of aquifers, recharge and discharge locations and responsiveness.

Model inputs specifically for the WAFL tool are:

- Annual change in streamflow for each subcatchment. This is automatically populated from the GIS interface using the TasLucas equations.
- A ‘Rainfall factor’ used to multiply all rainfall inputs to allow investigation of the effects of long-term changes in rainfall on streamflow.

Groundwater

Groundwater assumptions are at this stage necessarily simplistic but in future will need to be refined regionally based on broad knowledge of surface-deep aquifer attributes and linkages – especially with regard to longer term (seasonal to multi-year) lag and storage effects. There is also a growing local technical and public awareness of the groundwater interception–recharge issue. Consideration should be given to incorporating a medium to long term groundwater storage component into the AWBM models or WAFL tool. There is a spatial data layer for the state on broad characteristics and locations of differing groundwater flow systems (GFS), with greater resolution in the Midlands (NAP region). DPIW experts should be consulted on this issue, and their thoughts sought on how to incorporate GFS’s into the AWBM models (including thoughts on how to handle uncertainties on spatial dynamics of recharge and discharge).

Seasonal variation in EPT

Disaggregation to daily is only done using information from gauged flow series. The WAFL tool uses the TasLucas yield changes with the assumption that the annual change in yield is evenly distributed through the year (in proportion to streamflow pattern). However, presumably there is a seasonal component to EPT of forests (particularly young plantations). For example, do young plantations have higher EPT during summer than winter? If so then it may have a substantial influence on yield during low flow periods form subcatchments with large areas under new plantation. There should be enough understanding of this to introduce a broad seasonal adjustment to the TasLucas outputs. If it is demonstrated to be a small factor then it could be left out, but it should be explored. If it is significant (for large areas under high EPT forest) then even a rough estimated adjustment would be better than none.

Hydrological outputs

It is important to note that the WAFL project adopted hydrological indices cited in the original MDBC SRA hydrology framework. These were based on an approach developed for the SRA by SKM, which has recently evolved (with some significant changes) into the Flow Stress Ranking (FSR) method. This FSR method is also going to be used in the new Tasmanian River Condition Index methodology (TRCI). During refinement of the method into the FSR approach, a comprehensive analysis of index redundancy was conducted resulting in the recommendation of five indices which reflect the variation in stream hydrology due to human impacts.

As a result, three of the four indices output by the WAFL tool are no longer used in the FSR output (and hence the SRA and TRCI) and the method for calculating the Hydrological disturbance index has also changed. The revised set of indices used in the FSR method are:

- Seasonal period shift (a WAFL index output)
- Monthly CV (would need additional WAFL output)
- High flow frequency (would need additional WAFL output)
- Low flow frequency (derivable directly from the WAFL output)
- Proportion of zero flow (derivable directly from the WAFL output)

The SRA has, in addition, decided to retain Mean and Median Annual Q indices (the former being a WAFL output).

All of these are readily derived from the WAFL daily time series and/or outputs, and I recommend that the outputs be modified in the future to match the revised set of indices.

Number of cease to flow days (and proportion of time as zero flow) is the most error prone of any hydrologic model outputs. I recommend emphasising low flow frequencies and events rather than absolute zero flow, and ensuring caveats are provided about low accuracy of zero flow statistics.

3.3 Ecological condition

The WAFL Tool uses a set of data and relationships developed within CFEV (the Conservation of Freshwater Ecosystem Values) framework on condition of aquatic environmental assets. Thee are the most up to date and relevant to Tasmanian conditions.

The assessment in the WAFL tool of the riverine environmental implications of changed water yield driven by changed landuse focuses on quantifying changes to several key indices of condition: RS_SEDIN, RS_FLOW, RS_GEOM, RS_BUGSCO, RS_BIOL and RS_NSCOR. All of these are dependent on the Flow Abstraction Index, RS_ABSTI, which is derived within WAFL by substituting the change in mean annual flow from the AWBM model for the value in CFEV.

The mapping of rule sets to condition bands in WAFL closely matches those used in CFEV. The changes in stream flow predicted by the use of the TasLucas equations will generate appropriate changes to the overall condition band ascribed to each of the indicators, and provide a relative assessment of the risk to river ecological values. A similar approach could be applied, if the scale of land use change modeled by WAFL were sufficiently large, to wetland and estuarine assets, for which data is also available in CFEV.

3.4 Landuse and vegetation data

The requirements for land use data in WAFL (as attributed GIS polygons) is simple and should be readily achieved.

Forestry data will need to be sourced from Forestry Tasmania and the private forest sector. These data are not in the public domain, and data-sharing agreements may need to be established.

Future land use scenarios can be constructed with WAFL allowing for three changes in forest cover, these are:

1. conversion from pasture/agriculture to plantation;
2. conversion from native forest to plantation; and
3. harvesting of native forest followed by native forest regrowth.

Forecast changes in these three landuses can be integrated within the one scenario using WAFL.

The major issue with input data is landuse other than Forestry. TasVeg data may be out of date or locally inaccurate, though at sub-catchment scale and for current purposes it may be satisfactory. If more sophisticated comparisons including a range of non-forest landuses is required, then more accurate data will be needed. TasVeg data is crucial and DPIWE NRM branch should be urged to provide adequate support for its management and updating.

3.5 Abstraction data

By far the most important driver of yield change is abstraction. It is also highly prone to error unless data is gathered by metering. Current records of licenced takes in the WIMS database are often inaccurate in volume and location. Unlicensed takes and farm dams are also a major feature of the landscape. Improvements in these data sources are being sought and should continue to improve.

4. Use of the tool

Key issues for the use of the WAFL tool are discussed below.

4.1 Scale of assessment

The spatial scale for application of the WAFL tool appears to be limited by:

- The smallest size at which the TasLucas equations operate – defined by the smallest size soc paired catchments used to developed them. This is of the order of 2 km^2.
- The smallest scale at which the AWBM models can be successfully calibrated. This has been discussed above. The size of the AWBM sub catchment units for Water Management Planning has already been established, but could be somewhat reduced if required.

The WAFL model is likely to be suitable for application at medium to small sub-catchment to catchment scales. It will not be applicable to the scale of individual coupes or properties. Assessments at these smaller scales are likely to require greater local knowledge of soils, groundwater systems and rainfall distribution and will need to be calibrated to local streamflow data. The modelling approach may also need to be changed.

WAFL is therefore applicable to broad scale assessment of the effects of interception for downstream yield, flow patterns water availability and environmental risk. It's main use will be to assess areas (subcatchments) at potentially higher risk under projected land use change (plantation and other forest management) and climate change scenarios. These areas should then ideally be the target of more detailed evaluation and/or application of conservative constraints on plantation areas or management (e.g. through dispersal of planting and harvesting in space and time).

4.2 Thresholds and Triggers

For WAFL to be a successful management and policy instrument, regional thresholds or triggers of yield change must be established, above (or below) which risks to security of supply and to the environment are likely to occur. Management prescriptions should then be tied to these thresholds.

The rule sets in CFEV already ascribe levels of change in mean annual runoff (using the ABSTI abstraction index) to changes in biophysical condition of some aquatic environmental features. These could be readily revised and adopted as environmental triggers is required.

4.3 Reference benchmarks

The benchmark used in WAFL assessments is the current (recent historical) state of streamflow, abstraction and land use. A 'natural' benchmark is also used, where the AWBM models are run in the absence of abstractions, and this is generally the major driver of changes in streamflow in agricultural catchments. However, the AWBM flow models are calibrated against recent historical streamflow data, and are thus constrained by current relationships between vegetation and water yield. Reference benchmarks which include older historical vegetation and landuse scenarios (e.g. 'pre-European natural') would need reconfiguring of the AWBM models.

Benchmarks needs to be discussed between stakeholders, as it is the basis against which the derived risks are assessed. It should be noted that most community concern with regard to impacts of changed land use and climate change relates to changes from the current situation, and not some historical state.

4.4 Including climate change

A simple rainfall adjustment factor is available in WAFL to change the overall mean position of rainfall sequences in the modelling to adjust for projected climate change scenarios, either on their on or combined with land use changes. However, a single scaling adjustment of the input time series may not be sophisticated enough. In the longer term, use of forecast rain series which take into account projected changes in overall yield, seasonality and intensity of events would improve this capability. For serious applications, landuse change response to climate change may also have to be included in input data layers.

4.5 Including other land use changes

The WAFL tool as it stands is limited to assessing grass-forest and forest-forest land use changes. The differences between various crops in water yield responses are small compared to their differences to forest, but there will be a need for improvement if scenario simulations are to be more realistic. The WAFL tool is modular however, and could readily perform assessment of other land use change, provided spatial data were available, and that defensible landuse/vegetation type–water yield models (equations) exist, developed to operate at appropriate spatial scales. It should be noted of course that abstraction tends to be the single largest driver of yield change, after climate variation, and errors in those data sets will tend to swamp small differences in land use.

Forecast fire and/or storm disturbance could be factored in if spatial data are available, resetting the age of forests within specific polygons. Individual streamflow relationships for fire disturbance could also be developed and included in the model if needed.

References

HEC 2005. NAP Region Hydrological Model Ringarooma Catchment. Hydro Electric Corporation, Report to DPIWE. Report No:118784 - Report-2. 22 pp.