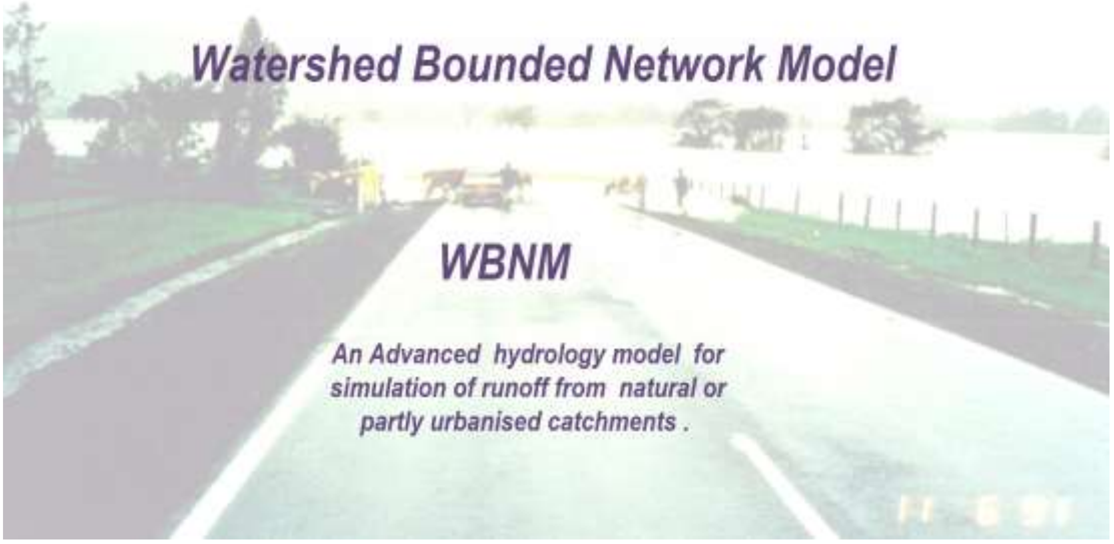

USER GUIDE

For all other details See:
WBNM_History.pdf
WBNM_References.pdf
WBNM_Runfile.pdf
WBNM_Theory.pdf
WBNM_Tutorial.pdf
WBNM_Validation.pdf

PROGRAM HISTORY IN BRIEF:

Previous versions : 1.00 1979 Michael Boyd, David Pilgrim and Ian Cordery

1.10 1987 Michael Boyd, Bryson Bates, David Pilgrim and Ian Cordery

2.10 1994 Michael Boyd, Ted Rigby and Rudy VanDrie

Previous versions of WBNM : 1.06 Initial beta release September 1999

	Version	1.07	September	1999
		1.08	November	1999
WBNM2000	Version	1.09	January	2000
		2.01	April	2000
		3.00	November	2000
WBNM2001	Version	1.00	June	2001
WBNM2002	Version	1.00	January	2002
WBNM2002	Version	1.01	July	2002
WBNM2003	Version	1.00	March	2003
WBNM2003	Version	1.01	August	2003
WBNM2003	Version	1.02	December	2003
WBNM2003	Version	1.03	June	2005
WBNM2007	Version	1.04	January	2007
WBNM2007_VLA	Ver sion	1.00	June	2007*
WBNM2009	Version	1.00	November	2009*
WBNM2010	Version	1.00	January	2007*
WBNM2012	Version	1.00	June	2012 FOS release
WBNM2017	Version	000	July	2017 Internal Beta*
WBNM2017	Version	000	November	2017 Public Release

* Limited release versions

All WBNM2003 and later runfiles are compatible with WBNM2012. WBNM2007 and later runfiles may include features that are not supported by earlier versions of WBNM. WBNM2017 introduced several changes to the runfile structure of WBNM2012. Refer Experienced User Notes. As such only earlier REC storm runfiles can be run by WBNM2017 without change.

Disclaimer

This computer software and the accompanying documentation has been written to transfer research carried out by the developers and other researchers, in flooding and stormwater management, to the engineering profession. The combination of academic researchers and engineering practicioners in its development makes WBNM ideally suited for use in the engineering office. We have taken considerable care in the development of the software and accompanying documentation making up the WBNM Software Package.

However, the software and the accompanying documentation should not be used as the sole source of information on flood studies. Reference should also be made to ARR 2016, textbooks and other published material. We have provided sample runfiles and full details of the model to help you understand how WBNM works. The onus is on you as the user to carefully determine whether your application of WBNM is correct, and to carefully review results to verify that they are correct.

WBNM provides extensive output of the calculations, both to the screen and to output files, allowing detailed checking of results. This information should be carefully reviewed by the user to confirm the validity of the results.

Users should read carefully the documentation provided with the WBNM software.

This User Guide is an abbreviated document to help you get started. For more details on the model, see WBNM_Theory.pdf.

Useful runfiles, covering a range of applications, are included in the *Sample Runfiles* folder

CONTENTS

1. What is WBNM ?

WBNM is an integrated software package for flood hydrograph studies on natural and urban catchments.

The two primary programs provided in this distribution are:

- WBNM_ENG: is a runfile engine for hydrologic and hydraulic calculations associated with runoff from user input rainfall (REC) storms. This is a FOS package intended to provide advanced simulation capabilities, as a plugin, to other software packages. All calculated results are optionally written to an output metafile for further post processing, with a runfile summary, including any warnings, to a QA file. This program is not discussed further in this documentation package – refer WBNM_ENG documentation.

- WBNM2017: is a comprehensive package for hydrologic and hydraulic calculations associated with runoff from user input rainfall (REC) storms, design ARR 1987 storms (DES87) and design ARR 2916 storms (DES16). This is a free compiled program intended to provide advanced simulation capabilities, for recorded and design storms in accordance with the provisions of Australian Rainfall and Runoff (1987 and 2016). All calculated results are optionally written to an output metafile for further post processing, with a runfile summary, including any warnings, to a QA file. This is the program discussed in this documentation

Additional utilities have been provided by others including:

- Iwbnm: a powerful utility to build a WBNM runfile and analyse/view results
- Convert_to_ts1: A utility provided by the developers of tuflow for reading wbnm results into Tuflow

It is understood that these are in the process of being upgraded to accommodate output from WBNM2017.

2. What WBNM Can Do

WBNM is an event based hydrologic model and calculates flood hydrographs from storm rainfall hyetographs. It can be used for modelling natural, part urban and fully urban catchments. For urban catchments, it calculates runoff from pervious and impervious surfaces and routes it through the major system of open watercourses. WBNM does not model the details of an underground piped drainage systems.

While the original concept was for a simple, yet physically realistic model, over the years WBNM has added many features to make it more useful for engineering investigations. WBNM was one of the first models to have built in culvert hydraulics, based on the US Department of Transportation charts, and among the first to have built in design storms for Australia.

The current version, WBNM has many features which make it a versatile and useful tool for flood studies. WBNM :

- is fully WINDOWS & LINUX compatible

- can use a template for easy runfile creation

- has comprehensive (optional) user selected outputs

- all hydrographs and hyetographs in the output files are in ASCII text and in columns, allowing easy cut and paste to other applications such as EXCEL

- optionally provides many summary result tables written to output files

- includes considerable checking to detect errors in your runfile

- includes a powerful debug capability, allowing examination of all results as they are calculated

- can be used in batch mode for multiple runs

- can model any number of subareas/etc (up to virtual memory limits)[1]

- can model a mainstream storage reservoir (outlet structure) on each subarea

- can model onsite detention storage (local structure) on each subarea

- can have any number of rain gauges[1]

- can calculate any number of time steps [1]

- can easily add or delete subareas without restructuring the model

- can easily add or delete local structures and outlet structures without restructuring the model

- can be calibrated on recorded rainfall and flood data

- allows rainfall to be entered as mm/hour or mm/period

- allows recorded hydrographs at any point in the catchment

- recorded hydrographs can be at the TOP or BOTTOM of the subarea

- allows hydrographs to be imported to any point in the catchment

- imported hydrographs can be at the TOP or BOTTOM of the subarea

- imported and recorded hydrographs can be entered as Discharge hydrographs, or as Stage hydrographs which are converted to discharge.

- recorded hydrographs, imported hydrographs, rainfall hyetographs and output results can have different time periods

- can provide design flood estimates in accordance with both AR&R 1987 and AR&R 2016 procedures

- allows multiple design storm runs[1] and allows design spectrums for a particular ARI/AEP to be run

- for extreme flood estimates, can switch from nonlinear to linear above a specified discharge

- can calculate embedded design storms in accord with the AR&R 1987 DFE procedures, where the critical duration burst is embedded within a longer duration event

- allows user nominated storm temporal patterns, as percentages of the storm total occurring in each time period

- rainfall losses for DES87 storms can be initial loss-continuing loss rate, or initial loss-runoff proportion, or Horton infiltration, or continuously time varying loss rate

- rainfall losses for DES87 and DES16 storms can be set 'GLOBALLY' (all same for all subareas) or individually for each subarea.

- routes hydrographs in stream channels separately from overland flow hydrographs

- stream channel routing can be nonlinear, time delay, Muskingum or Muskingum-Cunge

- can model natural, urban and part urban catchments

- calculates separate runoff hydrographs from pervious and impervious surfaces

- allows modification (eg urbanisation) to catchment surfaces separately from modification to stream channels

- can model onsite detention storage for pervious and/ or impervious runoff from a subarea (as an Outlet Structure)

- any proportion of the pervious and impervious runoff hydrographs can be directed to the onsite detention storage, with the remainder bypassing the storage

- can have rating curves at any point in the catchment

- gives a Stage hydrograph as well as a Discharge hydrograph at each Outlet Structure and Local Structure

- has built in culvert and weir hydraulics (both inlet and outlet control considered)

- culverts and weirs can be partly of fully blocked at a nominated time during the flood

- flows from each outlet in an Outlet Structure (ie culverts and weirs) can be directed to different downstream sub-catchments (up to 10 different sub-catchments)

- flows from each Outlet Structure can be directed to the Top or Bottom of the downstream sub-catchment

- surcharging flows can be directed out of the catchment

- surcharging flows can be calculated from the hydraulic relation of the appropriate outlet (ie a stream with breaking banks can be modelled as a weir)
- Local or Outlet Structures can have a dead volume to be filled before outflow commences
- Local or Outlet Structures can be part full at the start of the storm
- Local or Outlet Structures can have a scourable spillway, where the cross section is designed to scour as it is overtopped
- WBNM writes very detailed results of its calculations to various output files, allowing detailed checking, and allowing extensive post-processing.

Note:
1. There are no particular limits on array sizes in the model, but eventually the model is limited by the memory available to it. Models with over 3000 subareas and several hundred structures have been run successfully with the current (2017) model.

While WBNM can model many features of urban and part urban catchments, it does this on a broad rather than detailed basis. It does not model the detailed underground drainage system of gutters, inlets and pipes. These are best done by other models such as ILSAX / DRAINS or MOUSE.

3. WBNM Software Package

WBNM should be installed as supplied in a root directory *WBNM2017*, plus four sub-directories, *Executables*, *Documentation*, *Publications* and *Sample Runfiles*. The contents of these folders are :

WBNM Executables / Sub Folder

This folder contains :

- GLOBAL.INI
- WBNM2017_w64.exe
- WBNM2017_w32.exe
- WBNM2017_U

The GLOBAL.INI initialisation file allows you to customise your output in all runs. The global.ini file overrides the default values of the flags which are pre-set in the program. (A further PROJECT.INI file residing in your project directory can be used to in-turn over ride the GLOBAL.INI settings). GLOBAL.INI must be located in the same directory as your exe.

WBNM2017_w32.exe is a32 bit compiled version of wbnm for running under Windows.
WBNM2017_w64 is the 64 bit equivalent.
WBNM2017_U is the Linux/Ubuntu equivalent.

The version of the executable is printed out on screen and in the QA file each time the program is run.

Documentation Sub-Folder :

- Experienced User Notes.pdf
- WBNM_Readme.txt
- WBNM_UserGuide.pdf
- WBNM_Runfile.pdf
- WBNM_Theory.pdf
- WBNM_History.pdf
- WBNM_References.pdf
- WBNM_Tutorial.pdf
- WBNM_Validation.pdf
- WBNM2017Structure.pdf

Experienced User Notes summarises the changes from wbnm2012 to wbnm2017

WBNM_UserGuide.pdf gives information you need to run the model

WBNM_Runfile.pdf gives the structure of the runfile containing the input data

WBNM_Theory.pdf gives the theoretical background and assumptions used in the model

WBNM_History.pdf gives the various releases of WBNM

WBNM_References contains all papers referenced in WBNM_Theory.pdf

WBNM_Tutorial.pdf contains details of the sample runfiles, and an explanation of results. These sample runfiles cover many common modelling cases and are a good starting point for learning to use the model

WBNM_Validation.pdf shows selected recorded and simulated hydrographs for natural and urban catchments, ranging from very large to very small. This demonstrates the very wide range of applicability of WBNM.

WBNM2017Structure.pdf graphically describes the call structure of WBNM2017 for those interested in the programs internal structure.

Publications Sub-Folder:

Contains pdf's of selected published papers relevant to the model.

Sample Runfiles Sub-Folder :

The sample runfiles folder contains Wbnm_runfiles.txt which provides a list of all runfiles included in the sample folder together with a brief description of each.

The sample runfile folder also contains;

- The new_model_template.wbn that users can use to build a runfile from.
- Several batch files for test running the sample runfiles
- Various datafiles required to support the sample runfiles
- A PROJECT.INI set to minimise output.

Notes on the results for some of these files are given in **WBNM_Tutorial.pdf**

Note: WBNM takes your runfile name (eg Runfile.wbn), strips off the extension following the dot (.) and appends new endings for the various output files. These are:

Runfile_meta.OUT
Runfile_QA.OUT
Runfile_Culv.OUT
Runfile_Scour.OUT
Runfile_CritDes.OUT
Runfile_HplotCrit.csv (new in May 2018)

Therefore, your runfile **MUST** have an extension for WBNM to recognise the dot (.)

4. Getting Started with WBNM

The simplest way to get started with WBNM is to run one of the sample runfiles. While there are other options described in this document, it is easiest to 'associate' the wbn extension in explorer with wbnm2017_w64.exe (or w32 if a 32 bit windows OS). It is then only necessary to double click on the runfile to run the model. After the run, view the various output files with any text editor.

Try the following two runfiles. Natural.wbn is an example of a recorded storm and DES16_Sample_Catch.wbn is an example of an ARR 32016 design storm.

Once run, you should check that the Excess Rainfall Depth and the calculated Runoff Depth in the Storm Summary table are equal. This ensures that the runoff out of the model (calculated from the hydrograph out of the bottom subarea) is equal to the excess rain going into it (calculated from the rainfall hyetograph), and no water is lost. These should agree within a couple of percent. If they do not, either:

1) You have made a mistake in specifying the downstream subareas in the Topology Block, so that runoff from one or more subareas does not reach the desired location.

2) You have made a mistake in the subarea order in the Toplogy Block. WBNM calculates runoff from each subarea according to their order in this block. Therefore upstream subareas must be placed in the topology block before downstream subareas.

3) You have not provided a flowpath to convey water from the top of a subarea to the bottom of the subarea. Flowpaths are specified in the FLOWPATHS block.

4) You have directed flows out of the catchment at some point(s) other than the bottom subarea. If the case, this will create a warning message in your QA log file.

5) You have imported a hydrograph into the model. This is allowed, but the runoff will be greater than the excess rainfall.

6) If you model runoff from a catchment with an unusually extended lag (created by a large basin for example) calculations may end before the hydrograph has fallen to near zero. In this case the hydrographs calculated up to this time will be correct, but the volume remaining in the hydrograph tail will not be counted and this will underestimate the runoff volume. This effect will generally be minor. A quick check of the outlet hydrograph should confirm if this problem is present. It can be corrected by increasing the Snyder_lag in the INI file from its default (3) to a larger value.

With each run, a QA file is normallyy created. This takes the runfile name eg Runfile.wbn and appends an identifier, giving the file Runfile_QA.out. The QA file contains details of your organisation, the date and time of the run, the runfile name, and the storm summary for the bottom subarea. The QA file also contains any warnings generated during the run. This file is over-written each time you run WBNM.

By setting out_metafile= .TRUE. you can obtain a more detailed output file with the name Runfile_Meta.out This file contains hyetographs and hydrographs for ALL subareas. Because of this, it can be a very larger file particularly if the runfile includes storm spectrum runs.

After each run you should carefully check results. The WBNM summary tables, as well as the QA and META files can provide quite detailed information. You should check that there are no warnings in the QA file and that volumes and peak discharges in the summary tables are sensible. If the model has *Outlet Structures* or *Local Structures*, where flood routing of the hydrograph occurs, you should set the *Sum_outlet_structures* and/ or S*um_local_structures* flags to TRUE in the global.ini or project.ini files. This will write summary details of the volumes, peak discharges and maximum water levels to the META file. You should then carefully examine these results for accuracy.

Some applications of WBNM may be complex, and in these cases results should be carefully checked against independent calculations. These may include:

Outlet control calculations in culverts. WBNM uses the US Dept. of Transportation Federal Highways Administration Circular 5, as outlined in the Austroads publication *Waterway Design*. By setting the out_culverts flag to TRUE, detailed results of these calculations are written to an output file.

Rapid changes in storage volume or in discharge with elevation in storages (both Outlet Structures and Local Structures) may affect the level pool flood routing results. This may result in oscillations in the outflow hydrograph from the storage, particularly if the calculation time step is too large. You should examine the hydrographs for the storage. If oscillations occur, check that the rapid increase in storage or discharge in your runfile is correct. The problem can often be solved by reducing the calculation time step. Rapid changes in storage or discharge can be legitimately used to model particular features of the catchment. Examples of this are given in the sample runfiles Storage_divert.wbn, Offstream_storage.wbn, HED_onsite_detention.wbn.

Scouring embankments. Once the embankment starts to scour, rapid increase in the scoured dimensions and consequently the outflow discharge can occur. A small calculation time step is recommended for these cases. See sample runfile Storage_scourable.wbn.

5. The GLOBAL.INI, PROJECT.INI files and default values

WBNM has various flags to control the writing of results to output files and to control debugging.

Default values of these flags are set in the program source code.
You can override all or any of these flags by specifying them as TRUE or FALSE in the GLOBAL.INI file. Similarly, for a particular project, you can override the global values by specifying them in the PROJECT.INI file.

The flags for creating different output files are:

Out_QAsum writes out an echo of the runfile, any warning messages created by the run and provides a summary for each storm in the runfile. This QA log file has the same name as the runfile, but with an identifier appended, becoming Runfile_QA.out

out_metafile writes details of all event hyetographs and hydrographs to an output metafile together with any event summary tables if requested. It also includes a summary for each storm in the runfile if requested. This metafile has the same name as the runfile, but with an identifier appended, becoming Runfile_Meta.out

out_culverts writes details of culvert calculations to an output file Runfile_Culv.out

out_scourable writes details of the erodible spillway calculations to an output file Runfile_Scour.out

out_CritDes writes out a summary of design peak flows for each subarea for each duration together with a summary of the critical duration and pattern for each subarea. This latter table also includes details of the adopted design hydrograph's peak flow, peak timing and volume for each subarea. This flag also triggers creation of a Hplotcrit.csv file that includes a listing of all critical events in the run. This can also be manually created or trimmed as desired to use as input to the python utilities for plotting results.(May 2018)

The flags for summary table event output to the metafile are:

sum_catchments
sum_subareas
sum_depths
sum_volumes
sum_local_structures
sum_outlet_structures
sum_Qpeaks
sum_Tpeaks

These flags are described in more detail later.

The flags useful for debugging are:

dbg_echo writes an echo of the runfile to the echo log file as a check of what WBNM understands it has read.
dbg_run writes many intermediate values to the debug log file as they are calculated, allowing step by step checking of program operation

Note that when debug_run is activated, running WBNM for large models particularly when design spectrums are included takes considerably more time to run and can produce an extremely large debug log file in the process.

WBNM also allows you to enter details of your organisation, address and so on to customise outputs . These are:

org_name
org_function
org_street
org_city
org_state
org_country
org_zip
org_phone
org_fax
org_email
usr_name

You can specify when hydrographs being written to the output summary and metafiles are terminated. The default is 5% of the subarea outflow peak discharge. You can vary this by specifying an integer value, ie **trig_flowmin** = 10
If trig_flowmin is given a negative value, eg –500, writing of hydrographs is terminated after 500 time steps.
NOTE - trig_flowmin **must be** an integer

If trig_flowmin is set at a large positive value, hydrographs written to the output file are considerably truncated, and this reduces the size of the output file. Note that the hydrograph calculations in WBNM continue over the full range of time steps and are **not** truncated.

6. Controlling Output using the SUM Flags

WBNM writes various summaries of the results for each event to the meta output file.

If the SUM_CATCHMENT flag is set to TRUE :

Total catchment area (hectares)
Average impervious percent
Average rainfall depth (mm)
Average excess rainfall depth (mm)
Calculated runoff depth (mm)
Recorded runoff depth (mm)
Calculated peak discharge at catchment outlet (m^3/s)
Recorded peak discharge at catchment outlet (m^3/s)

The average rainfall and excess rainfall depths are calculated by multiplying the depth on each subarea by its area, summing for all subareas, then dividing by the total catchment area.

The calculated runoff depth is calculated from the volume of the hydrograph at the catchment outlet, divided by the total catchment area. This should agree with the average excess rainfall depth. If it does not, you have probably not connected up the subareas correctly (ie you have used a wrong downstream subarea name). This comparison is therefore a good check for errors in the runfile. Note that there may not be exact agreement between these values, either due to the straight line approximation of the hydrograph across each time step, or because a long hydrograph tail is chopped of, resulting in a loss of calculated volume. A difference of this kind does not affect the accuracy of results. Note that if you use a short time step for calculation with a very long duration event, the 2592 calculated values may not include the final part of the hydrograph tail. The calculated runoff volume then may be less than the average excess rainfall depth.

The excess rainfall and calculated runoff depths may not agree in some special cases. If you direct flow (ie from a point of surcharge) out of the catchment, the runoff depth (at the catchment outlet) will be less than the excess rainfall depth. If you import a hydrograph into the catchment, it will be greater. If you have a storage reservoir/ flood detention basin with “dead” storage which must be filled before outflow commences, the calculated runoff volume and depth will be less than the excess rainfall depth. If you have a Local or Outlet Structure/ flood detention basin which is part full at the start of the storm, the runoff volume and depth at the outlet will be greater. You can check these volumes and depths in the DEPTH and SUM_VOLUMES tables.

If a recorded flood is being modelled, the calculated and recorded runoff depths should agree. If they do not, you will have to adjust the rainfall losses accordingly.

If the SUM_SUBAREAS flag is set to TRUE, for every subarea :

Subarea Name
Subarea centre of area coordinates (E , N)
Outlet of subarea coordinates (E , N)
Downstream subarea Name

followed by :

Subarea Name
Area (hectares)
Running Area (hectares) – the total upstream area contibuting to this point
Impervious percent
Codes indicating whether a Stream Channel, Outlet Structure, Local Structure is present
Discharge above which routing changes from nonlinear to linear

The codes are calculated within WBNM depending on the data in the runfile. The discharges for nonlinear/ linear routing take the value in the runfile (for the catchment outlet) and factor it by the square root of the ratio of upstream area contributing to this point / total catchment area. See WBNM_Theory.pdf for more detail.

If the SUM_DEPTHS flag is set to TRUE, for every subarea :

Subarea Name
Rainfall depth (mm)
Excess rainfall depth for pervious surfaces (mm)
Runoff depth for pervious surfaces (mm)
Excess rainfall depth for impervious surfaces (mm)
Runoff depth for impervious surfaces (mm)

The excess rainfall depth is calculated from the rainfall hyetograph for the subarea after subtracting the rainfall losses. The runoff depth is calculated from the volume in the runoff hydrograph, divided by the subarea size. The excess rainfall and runoff depths should agree in each case.

If the SUM_VOLUMES flag is set to TRUE, for every subarea :

Subarea Name
Total volume directed to top of subarea, consisting of all hydrographs directed from upstream subareas (thousands m^3)
Volume of an external hydrograph which is imported to this subarea (thousands m^3)
Runoff from pervious surfaces (thousands m^3)
Runoff from impervious surfaces (thousands m^3)
Total volume of hydrographs directed from upstream storage reservoirs to the bottom of the subarea (thousands m^3)
Outflow from the subarea outlet (thousands m^3)
Balance (thousands m^3)

You can use these volumes to trace the movement of water from subarea to subarea of the catchment, and so to check that volumes are properly accounted for.

The balance sums all inflows to the subarea less all outflows. This should be close to zero, except for the special cases listed earlier. For onsite detention storages or storage reservoirs, dead volumes and initially part full storages can make the balance different to zero, but you can check that volumes are correct by adjusting for these values of the initial and dead storage. Also, for these types of storages, if the surface area is greater than zero, rain falling directly on the surface will be added in, and appears in the outflow, but is not shown as an inflow (since it is not a hydrograph from upstream). For each storage, the summation is :

Balance = Initial storage+Upstream hydrograph inflow+Rain on surface-Outflow-Final storage

This calculation is given in full in the SUM_OUTLET_STRUCTURES and SUM_LOCAL_STRUCTURES summary tables.

Note that the volume balance is in thousands of m^3 so this value could be large if the other values are large. However the volume balance as a percentage of the inflows and outflows should be small.

If the SUM_QPEAKS flag is set to TRUE, for every subarea :

Subarea Name
A code (0 or 1) indicating whether an Outlet Structure is present at the subarea outlet
Peak discharge at top of stream channel, consisting of all hydrographs directed to this point from upstream subareas, plus any imported hydrographs (m^3/s)
Peak discharge at bottom of stream channel after channel routing (m^3/s)
Peak discharge from pervious surfaces (m^3/s)
Peak discharge from impervious surfaces (m^3/s)
Peak discharge of any hydrograph directed to the bottom of the subarea (from an upstream storage reservoir)
Peak discharge into storage reservoir/ flood detention basin surfaces (m^3/s)
Peak discharge out of storage reservoir/ flood detention basin surfaces (m^3/s)

The discharge into the storage reservoir consists of the hydrograph at the bottom of the stream, plus any hydrograph directed to the bottom of the stream, plus local pervious and impervious runoff.

If the SUM_TPEAKS flag is set to TRUE, for every subarea :

Subarea Name
A code (0 or 1) indicating whether an Outlet Structure is present at the subarea outlet
Time to peak discharge at top of stream channel (minutes)
Time to peak discharge at bottom of stream channel (minutes)
Time to peak discharge from pervious surfaces (minutes)
Time to peak discharge of any hydrograph directed to the bottom of the subarea (from an upstream storage reservoir)
Time to peak discharge from impervious surfaces (minutes)
Time to peak discharge into storage reservoir/ flood detention basin surfaces (minutes)
Time to peak discharge out of storage reservoir/ flood detention basin surfaces (minutes)

If the SUM_OUTLET_STRUCTURES flag is set to TRUE, for every subarea with an Outlet Structure :

Subarea Name
Initial storage volume at start of flood (thousands m^3)
Inflow volume (thousands m^3)
Outflow volume (thousands m^3)
Final storage volume at end of flood (thousands m^3)
Balance (thousands m^3)

followed by :

Subarea Name
Inflow peak discharge (m^3/s)
Outflow peak discharge (m^3/s)
Inflow volume (thousands m^3)
Maximum volume stored during flood (thousands m^3)
Maximum water elevation in the storage (m)

The Inflow volume and Balance for storages are calculated differently from those in the SUM_VOLUMES table, because they refer specifically to the storage, and are not used to trace volumes from subarea to subarea.
.
The Inflow volume is the sum of all hydrograph inflows to the storage (from the stream channel, and local pervious and impervious runoff), plus rain falling on the storage surface area. The Outflow volume is the total hydrograph outflow from the storage. The Balance is the Initial storage, plus Inflow, minus Outflow, minus Final storage. This balance should be close to zero in all cases.

The inflow and outflow peak discharges and the inflow volume allow a quick check on the reservoir flood routing, and also allow for quick preliminary design of flood detention basins. (see Preliminary Detention Basin Design in WBNM_Theory.pdf).

If the SUM_LOCAL_STRUCTURES flag is set to TRUE, for every subarea with a Local Structure :

Subarea Name
Initial storage volume at start of flood (thousands m^3)

Inflow volume (thousands m^3)
Outflow volume (thousands m^3)
Final storage volume at end of flood (thousands m^3)
Balance (thousands m^3)

followed by :

Subarea Name
Inflow peak discharge (m^3/s)
Outflow peak discharge (m^3/s)
Inflow volume (thousands m^3)
Maximum volume stored during flood (thousands m^3)
Maximum water elevation (m)

The same comments regarding the Inflow volume and Balance as were made for the SUM_OUTLET_STRUCTURES summary table apply to the Local Structure.

7. Writing Results to Output Files

The QA and Meta Output Files

The QA file optionally provides a listing of the basic steps in the modelling process together with any warnings generated.

For each event , results can be optionally written to the metafile which takes the runfile name and appends an identifier, naming the file Runfile_meta.out. This contains all hydrographs for all subareas,. Additionally, the summary tables selected by setting the flags in the previous section to TRUE are also written.

This file is the prime source of detail result data for all simulated events but can be very long. Once a full (spectrum) run has completed it might be usefull to select the 'critical' events only and re-run for just those events.

All output files are over-written with each run of the runfile.

The Runfile_Meta.out file is used by WBNM for the summary table output. These results can be used directly in your own reports, or as input to other software such as EXCEL, Tuflow, HEC RAS or MIKE11/21. All output files are ASCII text files. Hydrographs and hyetographs are written in columns, allowing easy cutting and pasting.

8. Creating new Runfiles

Use your editor to open the blank runfile template(or a similar populated runfile) and save as your new runfile. Enter data into each block of the runfile (preamble block, Display block etc.).in accordance with the required data and format for that block. Often this data may be able to be cut and pasted from other applications (such as when building your model in GIS)

When entering data, it is good practice to save your runfile regularly. Once completed it is most important that the runfile be checked as described in the following before running.

It may also be helpful to compare your runfile with one of the existing runfiles from the Sample Runfiles folder as a guide to assist in understanding the arrangement of data in your runfile.

9. Utility Programs

WBNM2017 was extended in the May 2018 release to optionally output a plot control file in csv format that includes a listing of critical events for all subareas, resulting from a DES16 spectrum run. This csv file is called 'yourcatchment'_ hplotcrit.csv and iscreated in your runfile directory if out_critdes is .TRUE. Where the storm is a DES16 PAC run, only the subarea nominated for the PAC is included in the plot list.

A python utility called wbnm_hplotgen.py was also added to plot subareal hyetographs and all hydrographs for storms/events listed in a csv control file. This control file can be created manually or developed/edited from the DES16 csv event control file produced by wbnm for a DES16 spectrum. While the csv file produced by wbnm is specific to DES16 event, all event storm types are supported by hplotgen eg REC) (DES87) (EMB87) (DES16).

A python utility called wbnm_hplotpatts.py was added to overlay plot the listed events outlet hydrographs for each ensemble storm pattern for each DES16 event in the control csv file. It assumes the listed event is the critical dura/patt for the subarea (as is the case with the csv produced by wbnm) and highlights that listed pattern's hydrograph in red.

A python utility called wbnm_hyplotbox.py was added to provide box plots of peak discharge for each pattern for each duration in a DES16 spectrum run. The red solid box is the average discharge for each duration, the red line is the median discharge, the box extends from the upper quartile to the lower quartile of discharge results and the whiskers extend out to the full range of discharge data for that duration.

A python utility called wbnm_hubdl_all.py was added to directly download catchment hub data without having to power up a browser.

NOTE : While simple bat files have been created to run the python utilities for users unfamiliar with python - python 3.0 or higher must be installed on the system. The latest download of python from the (free) Intel python site is recommended.

10. Correcting errors in Runfiles

Errors in Runfiles

An error in the runfile which leads to an inappropriate value being read will be detected by WBNM stopping execution and giving an error message such as

“Invalid numeric input FILE=Runfile.WBN, UNIT=8, RECORD=**42**, POSITION=10”

This says that the inappropriate data is in line 42 of the runfile. Unfortunately, the NotePad editor in WINDOWS does not specify the current line and column. You might find it more convenient to use another text editor such as Notepad++ rather than Notepad.

You can correct the runfile by directly editing the runfile using a text editor. The WBNM_Runfile.pdf document will assist here, as will the sample runfiles in the Sample Runfiles folder, which cover most applications of WBNM.

NOTE: WBNM runfiles, and the global and project.ini files are ASCII text files. Therefore you should edit them using a text editor, such as NotePad or Notepad++. You should NOT USE Word or WordPad to edit these files.

Debugging Runfiles

If an error persists, set the dbg_run flag to TRUE. By setting dbg_run to true, it will write out a detail record of intermediate results to the debug log file, allowing you to trace the calculation of all values. This will help you identify the point at which the error occurs. Note that this writes voluminous amounts of data to the screen.

You can also set dbg_echo to TRUE. This will echo the input data from the runfile to the echo logfile as it is read, also helping you to track down the location of an error in your runfile. The last entry in this logfile will be the one immediately before the error.

Our experience with this and previous versions of WBNM is that virtually all problems encountered in running WBNM are due to (your) errors in constructing the runfile. If not, please let us know.

Checking Results

It is important that you carefully check results when a new catchment is being modelled. A common error is to not connect up the subareas correctly. This can be detected by comparing the depths of excess rainfall and calculated runoff for the total catchment in the Catchment Summary table written to the screen and output files. It is also useful to check volume balances for each subarea, and to trace the volumes going from each subarea to nominated downstream subareas, in the Volume Summary table.

When you run WBNM, any actual errors that occur will be flagged to the screen with some useful comment as to the reason for the error. All actual errors lead to termination of the program.

Even if the program runs without error, it is important to view the QA log file for warnings. Any warnings flagged should be carefully considered before accepting any results.

See also comments on results checking in section 4 Getting Started with WBNM.

11. Options for Running WBNM

Running WBNM2017 on WINDOWS :

Make sure you have the new global.ini in the WBNM2017 directory (appropriately configured for your purposes).

Make sure you have the new project.ini in the directory of your runfile (appropriately configured).

Running from the command line - in a command window type :

cd fullpath_to_my_runfiles

(eg c:\WBNM2017\SampleRunfiles) then type
full path to_WBNM2017_var.exe <space> mymodel.wbn
(eg c:\WBNM2017\WBNM2017_w64.exe Natural16.wbn)

Running from a batch file - (Note - relative addressing does not seem to work!)
For maximum reliability suggest formatting the batch file as follows;

REM move to the runfile drive
Z:
REM cd to the runfiles directory on that drive
cd Z:\projects\WBNM2017\SampleRunfiles
REM run WBNM2017 with the runfile
REM runfile and PROJECT.INI are now in the current directory
Z:\projects\WBNM2017\WBNM2017_w64.exe Natural16.wbn
The above command line can be repeated as many times as necessary.
Pause

Running Using Association
In windows the wbn runfile can be 'associated' with a program of your choice so that clicking the runfile executes that runfile with the associated program. If say WBNM2017_w64.exe is associated with files with a wbn extension, clicking on a runfile with that extension will run it with the associated program. This is probably the most efficient approach for those windows users that are normally running only a single wbn runfile at a time.

Running WBNM2017 on LINUX/UBUNTU :

!!!! NOTE LINUX IS CASE SENSITIVE !!!!!
Make sure you have the new global.ini in the WBNM2017 directory (appropriately configured for your purposes).
Make sure you have the new project.ini in the directory of your runfile (appropriately configured).

Running from the command line - in a terminal window type :

cd fullpath_to_my_runfiles
(eg cd /home/ted/projects/WBNM2017/SampleRunfiles) then type
full path to_WBNM2017 <space> mymodel.wbn
(eg /home/ted/projects/WBNM2017/WBNM2017_u64 Natural16.wbn)

Running from a script file - (Note - relative addressing does not work!)
For maximum reliability suggest formatting the bash script as follows;

cd to the runfiles directory
cd /home/ted/projects/WBNM2017/SampleRunfiles
run the engine with the runfile
runfile and PROJECT.INI are now in the current directory
/home/ted/projects/WBNM2017\/WBNM2017_u64 Natural16.wbn
The above command line can be repeated as many times as necessary.

12. Modelling Catchments with WBNM

Units

Coordinates of maps, subareas and rain gauges	(usually metres, but any consistent set)
Subarea size	(hectares)
Impervious percentage	(%)
Time, Delay time, Muskingum K	(minutes)
Elevation in storages	(metres)
Discharge	(m^3/s)
Storage volume	(thousands m^3)
Storage factor	(decimal, eg 0.9)
Culvert dimensions	(mm)
Weir length	(metres)
Weir coefficient	(SI units eg 1.70)
Discharge factor	(decimal eg 0.9)
Scour factor	(eg. 200 m^3/m^3)
Stream channel dimensions	(metres)
Stream channel bed slope	(% eg 0.5)
Stream channel side slope	(decimal ratio V:H eg 0.20)
Tailwater elevation	(metres)
Percentage of pervious, impervious runoff to Local Structure (%)	
Recorded Rainfall hyetograph	(mm/hour or mm/time period or percent)
Design Rainfall hyetograph	(mm/hour)
Rainfall period	(minutes)
Raingauge weighting factor	(decimal eg 0.9)
Area Reduction Factor	(decimal eg 0.95)
Terrain Roughness	(integer % eg 25)
Moisture Adjustment Factor	(decimal eg 0.63)
Initial loss	(mm)
Continuing loss rate	(mm/hour)
Horton infiltration rates	(mm/hour)
Horton k	(1/hour eg 2.0)
Runoff proportion	(decimal eg 0.75)

Note: all levels of water surfaces, culvert and weir levels, and tailwater levels are ELEVATIONS relative to your selected datum. Water DEPTHS are not used.

A Basic WBNM Model for Natural Catchments

This section contains an abbreviated description of information in WBNM_Theory.pdf

WBNM was originally developed for natural catchments, and is easiest to apply to this case. The catchment is divided into subareas by first identifying the main stream, then the major tributaries. The boundaries of the subarea draining to each tributary are then drawn, following the ridge or watershed line as defined by the surface contours. Each subarea will drain to the outlet of the tributary. These subareas (1, 2, 4 in figure 1) route excess rainfall to produce a flood hydrograph at its outlet.

Next, draw the boundaries of the remaining subareas, again using the surface contours. Note that these subareas (3, 5 in figure 1) route excess rainfall to produce a flood hydrograph at the outlet, and in addition route runoff from upstream subareas through the stream channel.

Subareas 3 and 5 therefore must have a stream channel with appropriate properties to convey the upstream runoff through them.

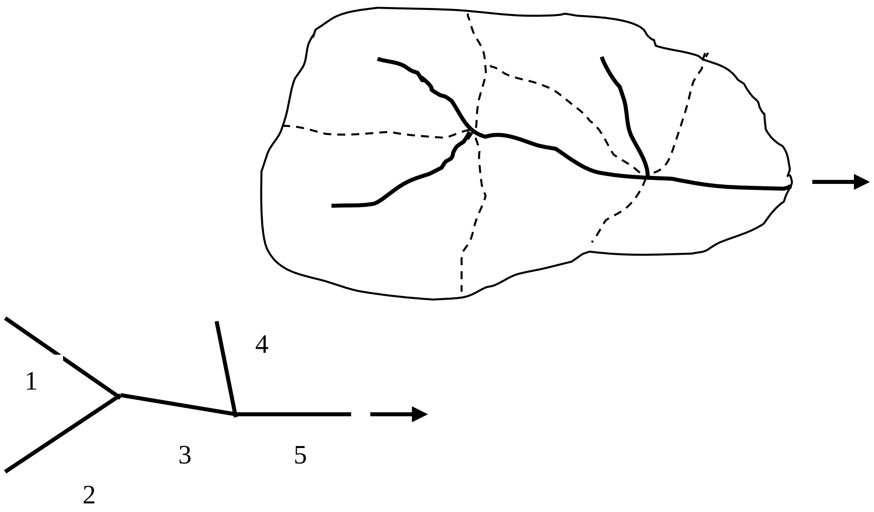

Figure 1. Dividing a Catchment into Subareas

Modelling More Complex Catchments with WBNM

The basic WBNM model is easy to set up, but somewhat limited in what it can do. WBNM has many options which give it considerable flexibility and allow complex flood studies to be carried out. We have aimed to introduce these options whilst retaining WBNM's essential simplicity by associating many of the options with each subarea, and allowing them to be switched on or off as required.

What each Subarea Contains

Each subarea can contain the following components (figure 2) :

- a stream channel from top to bottom
- pervious surfaces
- impervious surfaces
- onsite detention storage for local runoff from the subarea (Local Structure)
- storage reservoir/ flood detention basin on the main stream channel (Outlet Structure)
- subarea outflows directed to top of nominated downstream subareas (as nominated in the topology block)

- outlet structure outflows directed to top or bottom of nominated downstream subareas (as nominated in the Outlet Structures block)

The top of the stream channel takes all hydrographs directed to this subarea from upstream subareas, and all external hydrographs imported to the top of this subarea. These hydrographs are summed and routed through the stream channel to give a hydrograph at the bottom of the stream channel.

Pervious surfaces take the rainfall hyetograph for this subarea, subtract pervious rainfall losses, and route the excess rainfall to give a hydrograph from the pervious surfaces.

Impervious surfaces take the rainfall hyetograph for this subarea, subtract impervious rainfall losses, and route the excess rainfall to give a hydrograph from the impervious surfaces. A reduced lag parameter is used for impervious runoff.

The hydrographs from pervious and impervious surfaces are added to the hydrograph at the bottom of the stream channel, plus any hydrographs directed to the bottom of the subarea from the Outlet Structures of upstream subareas, plus any hydrographs imported to the bottom of the subarea, to give the combined hydrograph at the bottom of the subarea

Portions of the pervious hydrograph and impervious hydrograph can be directed into a Local Structure and routed through the storage. This routed hydrograph is added to other hydrographs at the bottom of the subarea. **Note that the local structure takes local runoff from the pervious and impervious surfaces in the subarea.**

An Outlet Structure (storage reservoir or flood detention basin) can be placed at the bottom of the subarea. If this storage is present, the summed hydrograph from the stream channel, plus any hydrographs directed to this point from outlet structures on upstream subareas, plus any imported hydrogrpahs, plus hydrographs from the subarea pervious and impervious surfaces, and from the subarea Local Structure, is routed through the storage to give an outflow hydrograph. **Note that the outlet structure takes local runoff from the subarea plus flow from upstream subareas.**

Finally, the hydrograph at the outlet of the subarea is directed to a nominated downstream subarea. If you direct it to SINK, the hydrograph is directed out of the catchment.

Within the Outlet Structure routing, outflows from the various outlets eg culverts and weirs, can be directed to various nominated downstream subareas. Each of these outflows can be directed to the top or to the bottom of the nominated downstream subarea. This allows for surcharging flows, which may take different flow paths to the normal one, to be redirected within the catchment. Again, if you direct them to SINK, the hydrograph is directed out of the catchment.

You can direct flows from any subareas, or from any outlet structures to any number of locations outside the catchment. For example, you might have flows from several points going to the ocean as well as to the bottom of the catchment. You can direct to (say) OCEAN as well as to SINK. Normally all flows will exit the catchment at the bottom of the subarea, going to SINK. In this case, the calculated runoff depth will be equal to the excess rainfall depth. If however you direct flows from other points out of the catchment, the volume reaching the bottom subarea will be reduced, and the calculated runoff depth (runoff volume divided by total catchment area) will be less than the excess rainfall depth.

If hydrographs are directed to the top of a subarea, a stream channel must be provided to convey these flows to the bottom of the subarea. If there are no hydrographs at the top of the subarea (ie if the subarea is at the upper end of a stream tributary - subareas 1, 2, 4 in figure 1) then a stream channel need not be provided. In this case the hydrograph from the subarea comes from routing of its excess rainfall hyetograph.

The foregoing paragraphs indicate that hydrographs coming from upstream subareas, as well as hydrographs imported from outside the catchment, enter the subarea at the **top** of its stream channel. This applies to all hydrographs following the normal flowpaths on the catchment, as specified in the topology block of the runfile. However with outlet structures, WBNM allows you to nominate whether the outflow goes to the top or bottom of the nominated downstream subarea. This feature is particularly useful for surcharging flows when the stream channel capacity is exceeded. This will commonly occur when two adjacent tributaries pass under an embankment. If, say, a blocked culvert in one tributary causes surcharge, the surcharging flows will go along the embankment into the adjacent tributary. They will typically enter the **bottom** of the adjacent tributary.

Further details of each of these operations are given in WBNM_Theory.pdf.

FLOWS in a SUBAREA

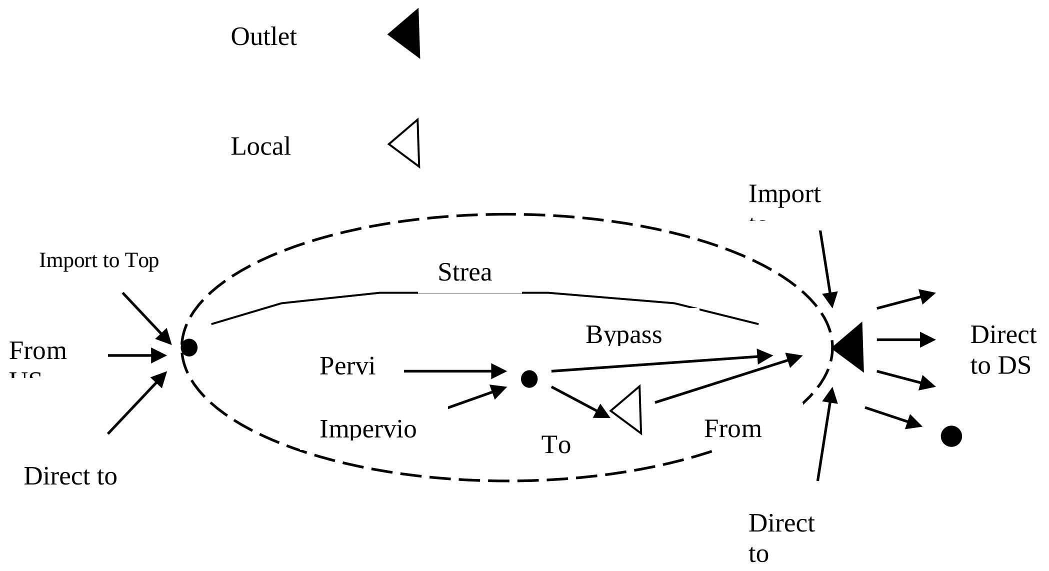

Figure 2. Components of a Subarea

NOTES :

1) Every subarea can have some or all of these components
2) Subareas conveying flow from Top to Bottom must have a Stream Channel
3) Flows from any number of upstream Outlet Structures can go to the Top and / or Bottom of this subarea
4) Flows from the Outlet Structure can be directed to up to 10 different downstream (DS) subareas, and can go to their Top or Bottom
5) The Local Structure takes runoff from the pervious and impervious surfaces of the subarea
6) The Outlet Structure takes runoff from the pervious and impervious surfaces of the subarea, plus runoff from Upstream subareas which has been conveyed from Top to Bottom in the Stream Channel, plus hydrographs directed into the subarea, plus hydrographs imported into the subarea.

Order of calculations in WBNM

WBNM calculates hydrographs subarea by subarea, starting at the uppermost one and moving downstream to the catchment outlet. If a subarea receives a hydrograph from an upstream subarea, this upstream subarea hydrograph must first have been calculated. Subarea hydrographs are calculated in the order in which they occur in the TOPOLOGY block of the runfile. Therefore the lowermost subarea in the catchment MUST be placed last in the topology block.

Within each subarea, calculations take place in the following sequence :

Flood routing from top to bottom of the stream channel

Rainfall hyetograph for the subarea calculated from surrounding rain gauges

Pervious surface local runoff hydrograph

Impervious surface local runoff hydrograph

Local structure storage routing of local runoff from the subarea

Summing of all hydrographs at the bottom of the subarea (stream channel hydrograph, pervious runoff, impervious runoff, outflow from local structure, any surcharging flows directed to the bottom of this subarea, any hydrographs imported to the bottom of the subarea).

Outlet structure storage routing of summed runoff at the bottom of the subarea

Directing flows to downstream subareas (if an outlet structure is present, you nominate whether flows go to the top or bottom of the subarea; if there is no outlet structure, flows go to the top of the subarea).

Note that to direct the flows from a subarea to a nominated downstream subarea, you must name the downstream subarea in the TOPOLOGY block (to direct normal flows) and in the OUTLET STRUCTURES block (to direct outflows from the storage reservoir). WBNM searches for matches of these named subareas when directing flows. Therefore you **MUST** use **exactly** the same name in all blocks of the runfile. WBNM similarly searches for matches of the subarea names to identify those with local and outlet structures, for rainfall losses, stream channel details, and so on. Again, you MUST use exactly the same names in all blocks of the runfile.

Note: you MUST direct flows from the lowermost subarea in the catchment to SINK.

13. Time Steps, Parameter Values, Initial values

Initial Discharges

WBNM is an event model, and the discharges are set to zero at the start of the storm. An exception to this is flood routing in storage reservoirs (Outlet Structures and Local Structures) which can be part full at the start of the storm. In this case, the initial discharge out of the storage is the value corresponding to the initial water level in the storage.

If you want discharges at all points in the catchment to be non zero at the start of the critical rainfall burst, use the embedded design storm option, in which the critical design burst is embedded within a longer duration design storm event. This will produce runoff in the streams before the critical burst begins.

Time Steps

Different time steps can be used for the rainfall hyetograph, the recorded hydrographs, the imported hydrographs, the time period used in calculations, and for writes to the output files.

The calculation period must be less than or equal to each of these other time steps. Each of the other time steps should be integer multiples of the calculation period. WBNM will automatically adjust these to be compatible with the calculation period, and will tell you of the change, in the QA and meta output files. This can particularly happen when using a design storm, when the rainfall period is set by the standard temporal patterns in Australian Rainfall and Runoff.

You may wish to use a smaller time step for calculations, but a longer time step to write the results to the output files.

During calculations, if the lag time for a subarea (which changes from time step to time step) becomes smaller than the calculation time period, solution of the nonlinear routing equations is no longer possible. If this occurs, execution ends and a message is sent to the screen telling you to reduce the calculation period. Simply change this value in the runfile, we suggest to half the original value. This is most likely to occur on small subareas when the discharges are large - for example a stream channel in a small subarea near the bottom of the catchment. In extreme cases, when the subarea size is very small, to avoid using an extremely small time step, you can replace nonlinear stream channel routing by a time delay (see Stream Channel Routing in WBNM_Theory.pdf for more details). Note that the calculation period can in most cases be quite large, usually equal to the standard hyetograph period for the selected duration design storm.

Flood routing through outlet structures and local structures may also require a small calculation time period. This may be necessary if culverts are used and a weir is set at a higher elevation. When the weir becomes active, discharges increase rapidly for a small increase in water level, giving an abrupt change in the elevation-storage-discharge relation, and requiring a smaller calculation period. A calculation period which is too large may cause outflow discharges to exceed the inflow peak. If this happens, WBNM will give a WARNING message.

Parameter Values

These are discussed in more detail in WBNM_Theory.pdf. This section contains a brief overview.

Flood routing for conversion of rainfall to runoff on pervious and on impervious surfaces, as well as flood routing in streams, all use particular values of the lag **time**. This lag time depends on the size of the subarea (ie larger subareas will have larger lag times), and WBNM has built-in relations which calculate the lag time for each of these processes. WBNM therefore uses a single value of a lag **parameter** which applies to all subareas. This basic lag parameter is adjusted by lag **factors** to calculate runoff from impervious surfaces, and for flood routing in streams. Thus WBNM essentially has three parameters:

Lag Parameter for conversion of rainfall to runoff on pervious surfaces

Impervious Lag Factor to reduce the Lag Parameter to a value appropriate to impervious surfaces

Stream Lag Factor to reduce the Lag Parameter to a value appropriate to flood routing in streams

For conversion of rainfall to flood runoff on natural catchments, and on pervious surfaces of urban catchments, an overall Lag Parameter value in the range 1.3 to 1.8 (average 1.6) will generally be used. Note, the Lag **Time** for each subarea is calculated as a function of the Lag **Parameter** and the subarea size, so that the same value of lag parameter should apply over a wide range of catchment sizes.

Routing in stream channels uses a similar lag relation, since the stream length is related to the subarea size, but with lower lag times because of the higher flow velocities in the stream. WBNM automatically does this. A Stream Lag Factor is used to adjust for changes to the stream channel. For undisturbed streams such as would be found on natural catchments, a Lag Factor of 1.0 is used. If the stream is modified by clearing, straightening, or concrete lining, flow velocities will increase and lag times will decrease. If, for example, the velocity increased by a factor of 2, the Stream Lag Factor would be 0.5.
Note, the lag **time** for routing in streams is the product of the **Lag Parameter** and subarea size (see previous paragraph) and the **Stream Lag Factor**. Normally, you will have a Lag Parameter which applies to all subareas, and a Stream Lag factor which applies to the stream in the particular subarea. Modifications to stream travel times are modelled by adjusting the Stream Lag Factor. If you reduce the **Lag parameter** for a particular subarea, you will also reduce the Stream Lag time, since this is a product of the lag parameter and the Stream Lag Factor.

Conversion of rainfall to runoff on impervious surfaces uses an **Impervious Lag Factor** to allow for the faster flow velocities on these surfaces compared to pervious surfaces. This will generally be near to 0.10.
Note, as for routing in streams, the **Impervious Lag time** is the product of the **Lag Parameter** and subarea size, and the **Impervious Lag Factor**.

Generally, we recommend that you set a single value of the Lag Parameter for all subareas in the catchment, (usually in the range 1.3 to 1.8, average 1.6). Changes to streams can be modelled by adjusting the Stream Lag Factor (or leaving it at 1.0), and runoff from impervious surfaces can be modelled by setting the Impervious Lag Factor to 0.10.

In unusual cases, you might reduce the Lag Parameter on a particular subarea. Note that this will also reduce the Stream Channel Lag Time and the Impervious Surface Lag Time, in the same proportion. Because WBNM has built-in relations to calculate the lag time for each subarea, and these are based on recorded data, this modification should only be used if you have strong evidence that you need to do it.

More details on calibrated lag parameter values for WBNM across Australia are given in WBNM_Theory.pdf and in the paper:

Boyd, M.J. and Bodhinayake, N.D. (2006). WBNM runoff routing parameters for South and Eastern Australia. Institution of Engineers Australia, Journal of Water Resources, 10(1), pp. 35-48.

Effects of Setting Parameters to Zero

It is worth noting the consequences of setting the various parameters and other values to zero. You may be able use this knowledge to model unusual cases.

1) Size of the subarea

If the AREA of a subarea is set to zero, local hydrographs from the pervious and impervious surfaces will not be generated.

Because the Lag Time for stream channel routing depends on the size of its subarea (the Stream Lag Time is a product of the overall model Lag Parameter, the Stream Lag Factor and the subarea size) the stream lag time will be zero and no stream channel routing will occur. The hydrograph at the bottom of the stream channel will be identical to that at the top of the stream channel.

2) Stream Lag Factor

If the stream lag factor is zero, the lag time in the stream will be zero and no channel routing will occur in that subarea. The hydrograph at the bottom of the stream channel will be identical to that at the top of the stream channel.

3) Impervious Lag Factor

If the Impervious Lag Factor is set to zero, no routing of excess rainfall on the impervious surfaces will occur. The runoff hydrograph from the impervious surfaces will be equal to the excess rainfall hyetograph (adjusted from mm/hour to m^3/s).

4) Overall Model Lag Parameter

Because the Stream Channel Lag Time and the Impervious Lag Time are products of the overall catchment Lag Parameter and the appropriate Lag Factors, setting the overall Lag Parameter to zero results in no routing of runoff from pervious or from impervious surfaces. These hydrographs will be equal to the corresponding excess rainfall hyetographs (adjusted from mm/hour to m^3/s). Similarly, there will be no routing in the stream channel and the hydrograph at the bottom of the channel will be identical to that at the top of the stream channel.

5) Storage Volumes in Outlet Structures and Local Structures

If you set all values of storage volumes in the Elevation-Storage tables to zero, no storage routing occurs and the outflow hydrograph is identical to the inflow hydrograph. This can be simply achieved by setting the Storage Factor at the end of the BASIN_DETAILS block to zero. This gives a simple way of temporarily switching off a structure such as a flood detention basin.

6) Discharges through Culverts and Weirs

You can quickly adjust the discharge through culverts and weirs by setting the Discharge Factor in the OUTLET_DETAILS block of LOCAL and OUTLET structures. A Discharge Factor of 0.9 for example, reduces the discharge for all heads to 90% of the full discharge. This can be used to model partial blockage of culverts and weirs by debris. Setting the Discharge Factor to 0 models a completely blocked outlet.

Calibration using Recorded Rainfall and Flood Data

As with any model, it is desirable to calibrate WBNM using recorded flood data wherever possible. In the absence of full hydrograph data, it may be possible to use observed maximum water levels to infer flood peak discharges with which to check results.

If a full set of rainfall hyetograph and flood hydrograph data is available, WBNM should be calibrated on this.

The graphics routines in WBNM can be used to examine the recorded flood hydrograph and recorded rainfall hyetographs. This will allow an estimate of the time at which surface runoff commences and the time at which excess rainfall commences. Rainfall before this time will be initial loss.

You can then adjust the continuing losses until the Excess Rainfall Depth and the Recorded Runoff Depth in the Catchment Summary table agree. This summary table will give a message telling you to increase or decrease the rainfall losses, as needed.

When the appropriate rainfall losses have been determined, you can adjust the model Lag Parameter to fit calculated and recorded hydrographs. The peak discharge would normally be used as the primary fitting criteron. An increase in the lag parameter will make the hydrograph occur over a longer time period, and reduce the peak discharge, and vice versa. Examination of the hydrographs will help in this adjustment.

14. Running Large Numbers of Storms or Storm Events

When running large numbers of storms or storm events, execution time may increase due to the large amount of data being written to the screen and to the output files. You can speed up execution time, and reduce the amount of output by setting the various flags appropriately:

Set the **dbg** flags in the Project.ini file to FALSE, this reduces output to the screen.

Set the **out** flags in Project.ini to FALSE, this reduces the amount of data written to output files. You can reduce output considerably by setting **out_metafile** to FALSE, however this will not allow any event data to be recorded.

Set the **sum** flags to FALSE in Project.ini, this reduces output to the meta file. To obtain sufficient information from your runs, you will have to set some flags to TRUE, and setting **sum_storms** to TRUE may be sufficient for your needs.

In most cases, you will wish warnings and storm results to be written to the QA file, so the summary output specified by setting sum_storms output to TRUE will appear in this file.

Before running large numbers of storms, it is important that you check that your WBNM model is set up correctly and is giving correct answers. You should do this by independently checking results for selected storms from the large number you plan to run.

---------------------------------- END OF DOCUMENT --