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User guide for *FluvialCorridor* toolbox

Extraction of the stream network

Toolset name : *SPATIAL COMPONENTS*

Tool's name : *Stream network*

How to cite : Roux, C., Alber, A., Piégay, H., 2013. Stream network guideline for the *FluvialCorridor* toolbox, a new ArcGIS toolbox package for exploring multiscale riverscape at a network scale. Sedalp (Sediment Management in Alpin Basins) and CNRS (UMR5600).

FluvialCorridor **package for ArcGIS**

Version V01 - 2014

CNRS - UMR5600 Environnement Ville Société
Alpine Space Program - Sedalp

For each use of the *FluvialCorridor* GIS package leading to a publication, a report, a talk presentation or any other document, please refer to the following paper :

Roux, C., Alber, A., Bertrand, M., Vaudor, L., Piégay, H., submitted. "FluvialCorridor" : A new ArcGIS package for multiscale riverscape exploration. Geomorphology.

I. Concept and method

In most geomorphologic studies, acquisition of a stream network is a first crucial step. To provide meaningful and operational results, at a large regional scale or locally oriented, the stream network has to be consistent. That is to say :

- oriented,
- connected and continuous,
- relevant of the in-field configuration.

Numerous works have already been done in this way. This has especially been shown by Lamouroux *et al.* (2008) and Pella *et al.* (2012) who created a connected and oriented hydrographic network named RHT (for Réseau Hydrographique Théorique). Such a data make the modeling and the assessment of environmental metrics easier at the catchment scale. For the RHT, the chosen process is the "Streamburning" (Hellweger, 1997). It enables to deeply inlay a polyline representative of the network into a digital elevation model (DEM) and so, to force the stream, assessed from this DEM, to pass through this network (Fig. 1).

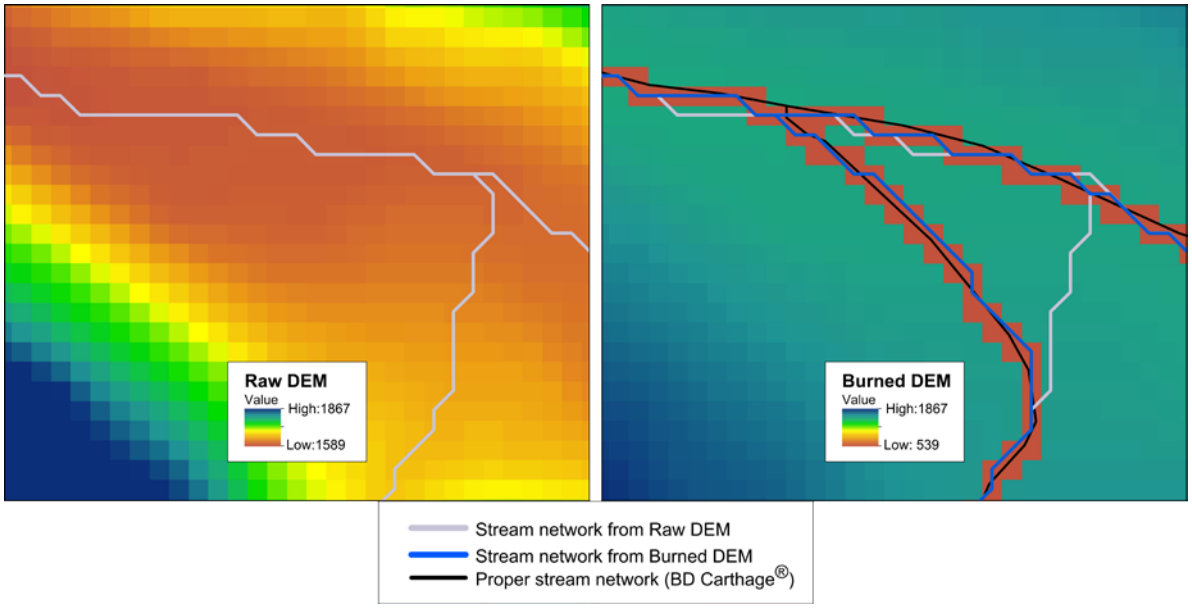


Figure 1 (A) DEM without streamburning step and the related stream network and (B) burned DEM, proper network used during the streamburning and the resulting network compared to the network extracted without streamburning. The resulting stream network is forced to pass by the inlaid network.

Implementation of this extraction method has been done with a GIS software (ArcGIS 10.0) thanks to a DEM (BD Alti® from IGN[1]) and a vector layer representing the stream network (BD Carthage® de l'IGN). The present *Stream network* tool can be used on any area covered by a DEM. If a pre-existing network is available (e.g. BD Carthage®, BD Topo®, for the French territory), a first step of "Streamburning" can be included.

[1] Institut Géographique National français

General algorithmic framework

The algorithmic scheme developed for the *Stream network* tool is presented in the Fig. 2. "*Streamburning*" option can be included to the workflow if a consistent pre-existing network is available. It is realized thanks to the function *DEMReconditioning* of *ArcHydroTools*, a free ESRI package. This toolbox must therefore be installed before using *Stream network* tool (see General Overview guideline for further details).
In any case, with or without "*Streamburning*", the DEM is processed through an usual workflow :

1. fill possible sinks in the raster surface with the *Fill* function (*SpatialAnalyst*)
2. assess the flow direction for each cell of the DEM : *Flow Direction* (*SpatialAnalyst*)
3. determine number of cell drained in each cell of the DEM with the *Flow Accumulation* function (*SpatialAnalyst*)
4. link streams at confluences with the *Stream Link* function (*SpatialAnalyst*)
5. finally, convert the raster stream network into polylines.

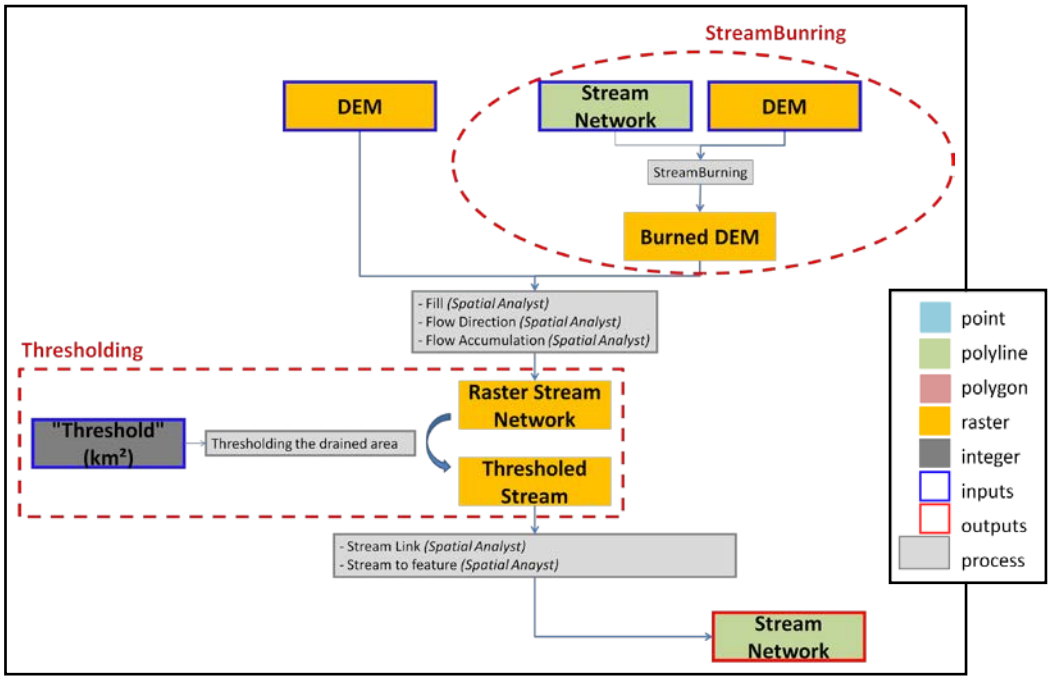


Figure 2 General algorithmic framework of the *Stream network* tool

Before sinking streams and converting them into polylines, a threshold is applied on the raster stream network. This step aims at fixing a given integer value of drained area to initiate the stream network and so to control its density. This threshold can be fixed empirically according to the study objectives.

Multi start points

Depending on the study area, the DEM size can highly vary and rapidly increase. The *Fill / Flow Dir / Flow Acc* steps can induce very long computation times. One of those raster layers could already be available. The *Stream network* tool can therefore be started at different steps:

- with the original DEM (the choice of including or not the "StreamBurning" is then available)
- with the filled DEM
- with the Flow Direction raster
- with the Flow Accumulation raster

} burned or not

About the streamburning management

The *DEMReconditioning* function of *ArcHydroTools* toolbox used to burn the DEM must be launch with a raster not contained into a geodatabase.
Moreover, before any compilation, *ArcHydroTool* needs a default destination to store the output entities. Thus, when the *Stream network* tool is launched, a folder and a geodatabase are created into the folder in which the DEM is stored. The created folder is named "Layers" (or "Couches" for the French version of ArcGIS) and the geodatabase has the same name than the folder containing the DEM. The burned DEM is stored into the created folder (Fig. 3). So be careful: the folder containing the original DEM should not already contain a geodatabase with the same name.
It is not recommended to delete the "Layers" file and the geodatabase during a session of ArcGIS.

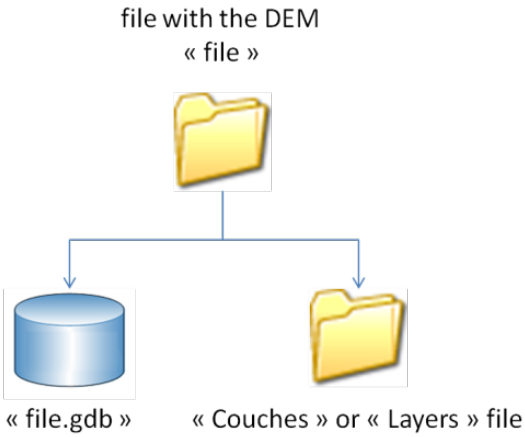


Figure 3 Files and geodatabase organization for the Streamburning management

II. Screen user interface

II.1. Start-up screen

Into the screen user, several fields have to be filled (Fig. 4). Be careful that a green mark in front of a field is not a guaranty that this field is not optional. Into *Stream network*, if a field is available, that means that it **must be filled**.
In general, the user starts by choosing the step of the process he wants to launch the tool (cf. "Multi point starts" chapter upper). If he decides to start with the original DEM, the "*Include Stream Burning*" field will be activated and then, the user has to choose to include or not this step to the general process. If yes, fields related to the "*Streamburning*" will be available, i.e. "*Network for burning*", "*Number of Cells For StreamBuffer*", "*Smooth Drop in ZUnits*", and "*Sharp Drop in ZUnits*". Further explanations about these parameters and the general principle involves during the streamburning are available into the tutorial of *DEMReconditioning* (*ArcHydroTools* package). Then, the user has to set the threshold used to initiate the stream network. This threshold has to be fixed in km^2. Finally, the user has to write the path and the name of the output stream network and also if he wants to keep or to erase temporary files created during the process.
One of the steps involves in the tool (*StreamToFeature* of *SpatialAnalyst*) needs a Flow Direction raster. That's why there is a field « Flow Direction raster », available only when the tool is launch with a Flow Accumulation raster. In the other cases, this raster is either created during the process or directly given by the user.

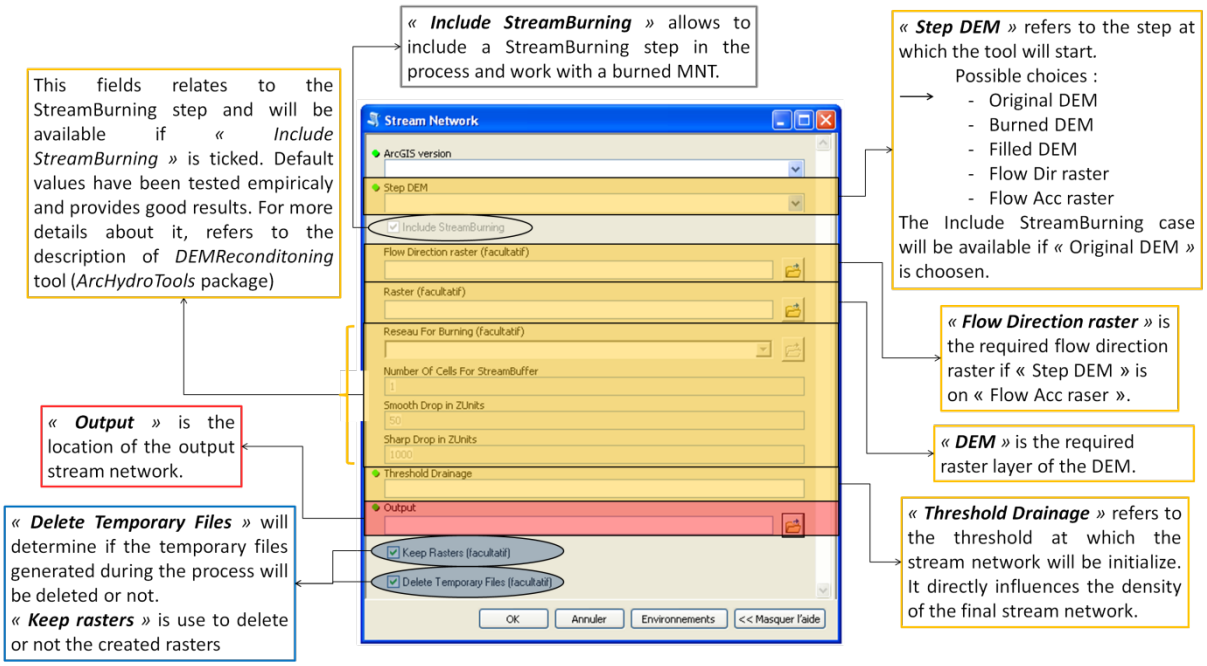


Figure 4 Screen user interface of *Stream network* tool

II.2. Management of temporary files

Temporary files created during the compilation are managed thanks to the ArcGIS default geodatabase (*%ScratchWorkspace%*). If the user does not modify this geodatabase in the general environment proprieties, its path must looks like C:\Documents and Settings\<user>\My Documents\ArcGIS\Default.gdb. With the box "*Delete Temporary Files*", the user has the choice to keep or erase temporary files.
Processing the *BurnedDEM*, *FilledDEM*, *FlowDir* and *FlowAcc* rasters is the most time consuming step but those rasters are often useful for geomorphological studies. Thus, it is possible to keep them by checking the box "*Keep Rasters*". The *BurnedDEM* is stored into the folder mentioned in the upper part "About the streamburning management".

III. Caution for use and limitations

III.1. Results

Presented results have been obtained thanks to the *Stream network* tool. Study area is the Durance watershed, in the French Southern Alps (Fig. 5). This catchment extends over 6313 km^2. Available material is a DEM (50m, 50m) from the BD Topo® and a linear feature of the hydrographic network (~ 4897 km) from the BD Carthage® and used for the streamburning. Both of them come from the French National Geographic Institute.

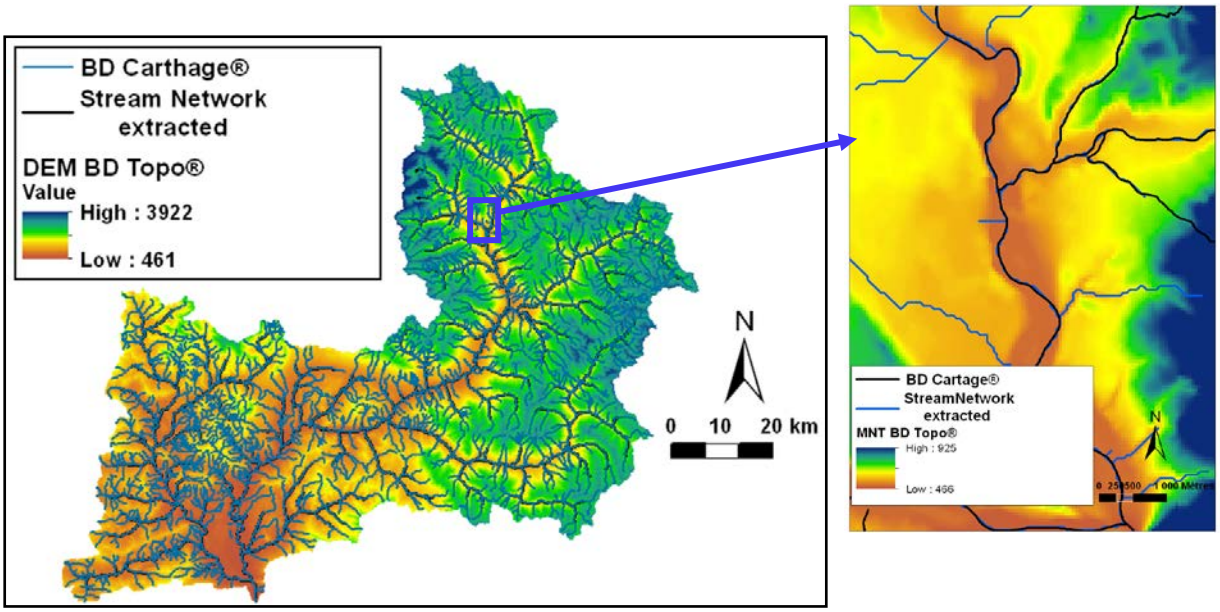


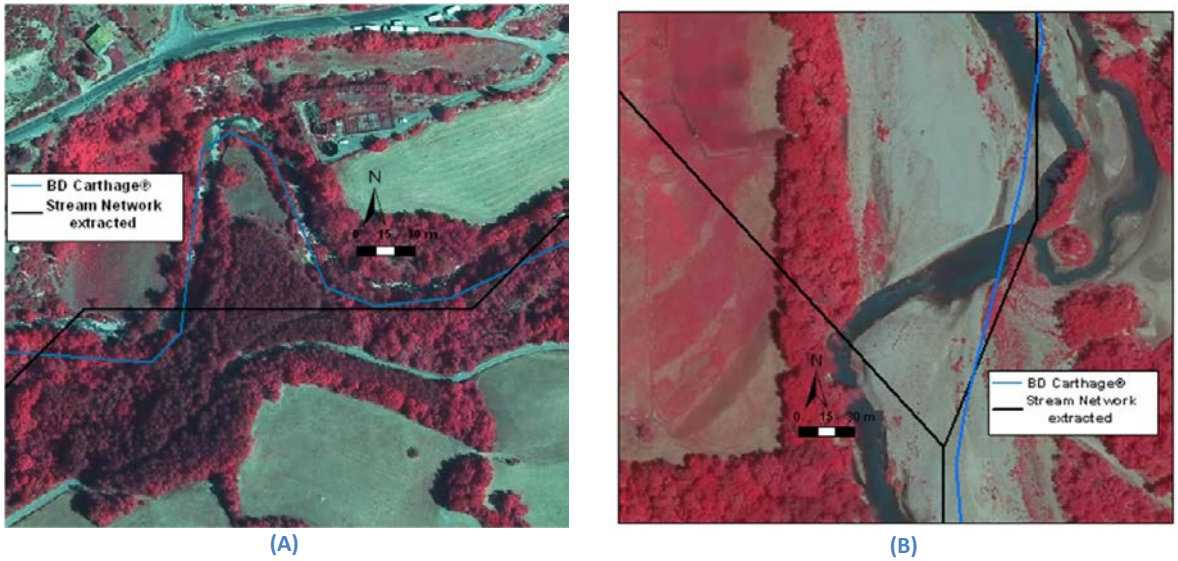
Figure 5 *Stream network* result for the Durance catchment (Southern Alps, France).

The stream network has been extracted with a drainage threshold of 1 km^2 and extends over 4162 kmkm. 3621 km km of the entire network overlay the BD Carthage stream network, i.e. 87%. Extracted stream network is split at each confluence so that it is composed by 3208 distinct streams. Each of them has a unique ID ("*OBJECTID*") and is oriented from upstream to downstream.

III.2. Non exhaustive list of cautions and limitations

a. Without streamburning

Without streamburning step, resulting stream network may include critical bias. It can be not representative of in-field observations (Fig. 6A). Those mistakes directly come from the DEM resolution. So this resolution must be consistent with the further uses of the output stream network (i.e. either regional or local). Drainage density also impacts. For too low values, unrealistic micro tributaries can appear (Fig. 6B).



(A) (B)

Figure 6 Wrong interpretations in a without streambunring stream network. (A) : wrong interpretation of the network or simplification for a very meander reach (B) : creation of unrealistic branches

b. Influence of the StreamBurning step

Streamburning step enables to force output stream network to overlay a pre-existing network while drainage density can be modified. This is surely the recommended solution to extract the stream network thanks to the *Stream network* tool but user must therefore remains vigilant. Accuracy of the pre-existing network used to force the DEM directly affects the output network accuracy. Two common mistakes are illustrated in Figure 7 with the BD Topo® streams. Although loops (Fig. 7A) and disconnected streams (Fig. 7B) are often correctly processed during a *StreamNetwork* run, it is recommended to provide a consistent network for the streamburning.

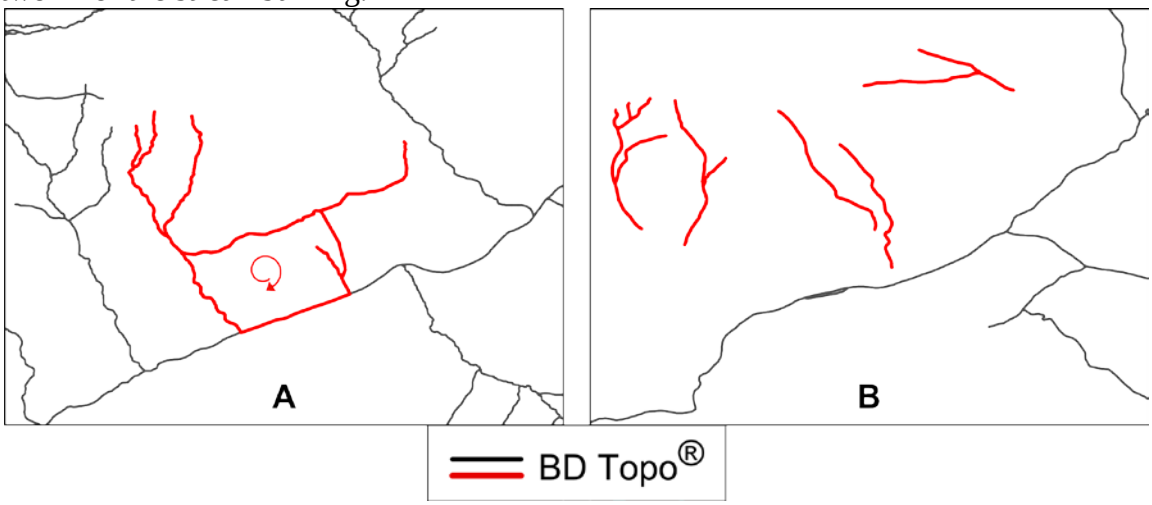


Figure 7 Disconnection or loops into the network used to burn the DEM (BD Topo®). In red, a loop (A) and several disconnected streams (B). These topological mistakes can affect the output stream network accuracy.

IV. References

Lamouroux, N., Stroffek, S., Pella, H., 2008. Estimkart : plate-forme de modèles sur SIG pour la gestion écologiques des débits à large échelle. Simulations et interprétation des premiers résultats sur le bassin Rhône-Méditerranée. Cemagref – Agence de l'Eau Rhône-Méditerranée-Corse – Onema, 19 p.

Notebaert, B. et Piégay, H., 2013. Multi-scale factors controlling the pattern of floodplain width at a network scale : The case of the Rhône basin, France. Geomorphology. http://dx.doi.org/10.1016/j.geomorph.2013.03.014

Pella H., Lejot J., Lamouroux N., Snelder T. Le réseau hydrographique théorique (RHT) français et ses attributs environnementaux. Géomorphologie : relief, processus, environnement, 2012, n°3, p. 317-336.

ANNEX 1

List of temporary files created during the *Stream network* tool

Name	Description
BurnedDEM	Original DEM after the streamburning process. It is stored into the "*Layers*" file created into the file containing the original DEM.
FilledDEM	Filled original DEM or burned DEM (*Fill* tool of *Spatial Analyst*)
FlowDirRaster	Flow direction raster (*Flow Direction* tool of *Spatial Analyst*)
FlowAccRaster	Flow accumulation raster (*Flow Accumulation* tool of *Spatial Analyst*)
Threshold Step	Thresholded *FlowAccRaster* with the user-defined drainage density.
StreamLink	Attributed raster stream network (*Stream Link* tool of *Spatial Analyst*).
Output	Final output shapefile of the stream network after conversion into polyline feature (*StreamToFeature* tool of *Spatial Anayst*).