Guidance for Flow Direction and Connectivity in Low Relief Areas

VERSION	DATE	CHANGE
1.0	3/12/21	First draft

This guidance document is being provided to help contractors make decisions about connectivity and flow directions in low relief areas, which is a complex subject and additional guidance will likely be needed in the future. This initial guidance paper should provide information on how to determine connectivity and flow directions in closed depression without apparent channels, closed depressions with apparent channels, and open depressions with apparent channels, but scenarios are possible and need to be considered. As more scenarios come up for discussion, this paper will be adjusted, but best judgement should be used by contractors and continued conversations should be had with USGS as the need arises.

Connectivity

1. If no apparent channel exists from a lake/pond to a network, keep it as an isolated feature.
2. Where depressions are nested inside a closed depression, no connectivity should be added between the inner depressions.
3. Where channels do exist, outside of closed depressions, adjust flow direction so that flow is toward a major stream/river feature or lowest elevation values.
    a. If the elevation surface does not support flow towards a major stream/river feature, use underground conduits (see underground conduits guidance).
    b. If a large depression is at a headwater area, keep it disconnected from the network. The low elevation values within the depression will make it too difficult to adhere to downstream monotonicity rules. Find the natural watershed divide and begin stream network there.

Flow Direction

1. Streams should always be digitized to point toward the direction of downhill flow.
2. Streams in low relief areas should point toward the direction the network is generally flowing, or toward areas with lower elevation values.
3. If a flow accumulation model appears to be directing a stream away from the general downhill network flow, evaluate whether:
    a. the stream belongs to a different part of the network.
    b. the stream could be removed – insignificant contribution to the network.
    c. The z-values could be adjusted within the rules for monotonicity in Alaska
        i. Can be adjusted if within 2 meters below the surface.
        ii. If absolutely required, can break the rules of monotonicity, if it is documented in the attribute table for the feature.

Recommendations and Examples:

Example 1: Considerations for identifying connectivity and flow direction in low relief areas with open and closed depressions, and waterbodies:

Note, the following examples and recommendations are not based on precise locations of channels and flow directions, they are only provided as an example of the general method.

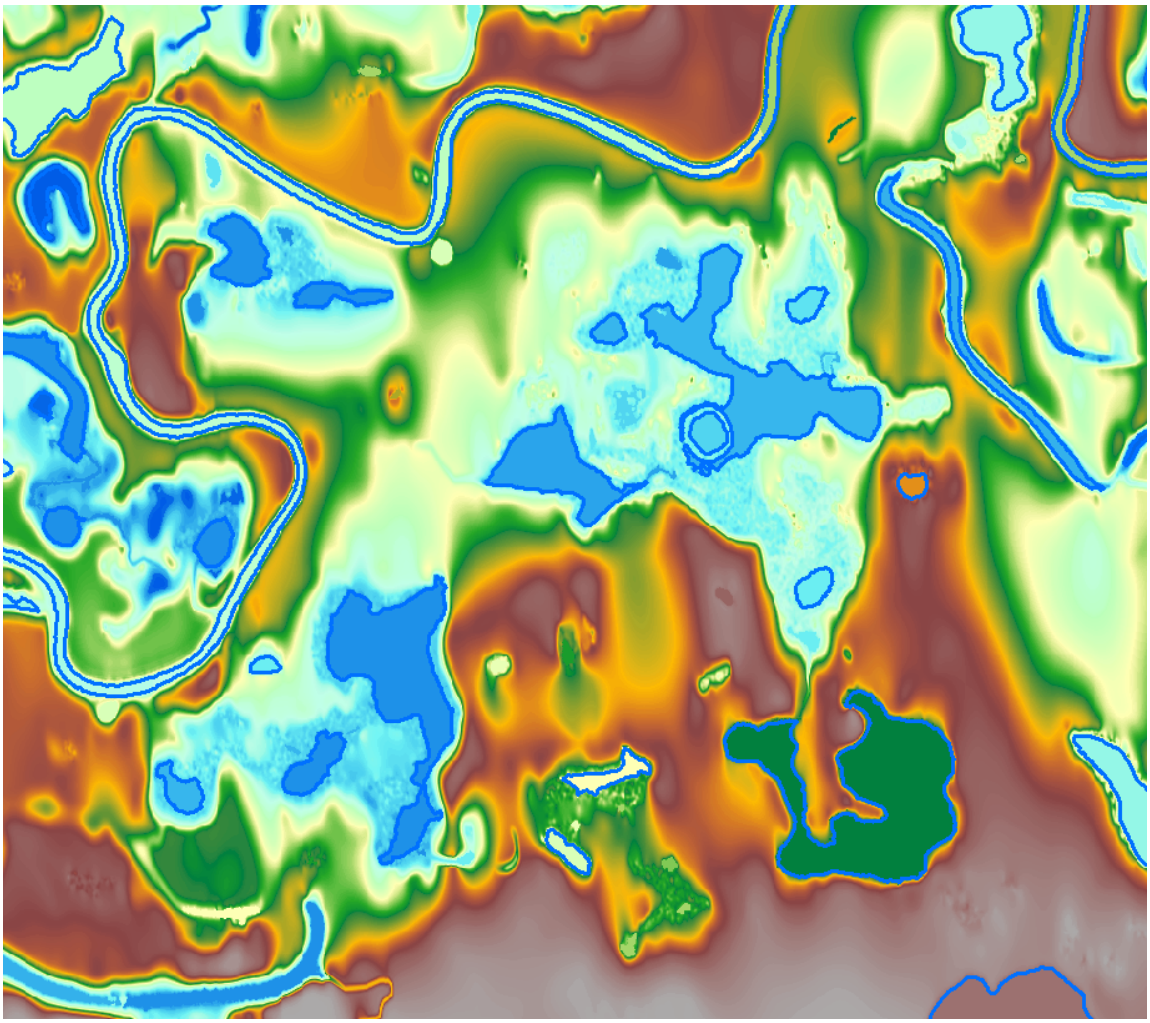
The general recommendation for connectivity in *low relief areas* with depressions and waterbodies is:

> **Do not create connectivity between features unless there is clear evidence of a stream channel**.

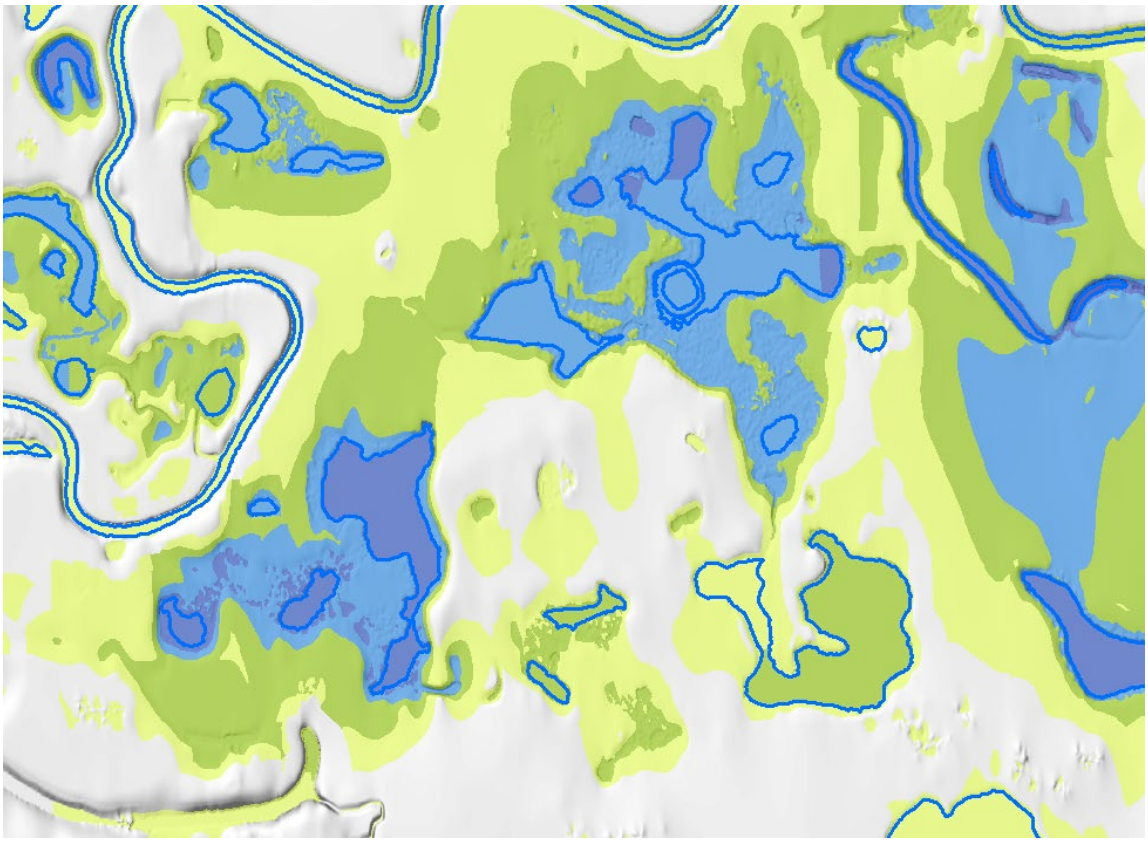
The following steps are examples of methods that can be used to determine locations where channels are needed to provide connectivity between depressions and waterbodies, i.e. clearly defined channels not found in closed depressions; and locations where channels are not required – those found in and between closed depressions. Each of these steps helps identify where channels may exist, and where there are no channels. Channels within closed depressions will not need to be added to the network. The process of identifying needed connectivity may require multiple steps to find true connected features.

Consideration 1: Determining if a depression is isolated or connected to a network:

A. Identify areas within a watershed that are lower than the primary stream channels that flow out of the drainage area
    a. Review the elevation – darker blue areas are the lowest areas. Note that the double line stream is a lighter blue (higher in elevation) than many of the lake features. Note that the elevation gradient is exaggerated for this image. The range of elevation values is about 10 meters in this area:



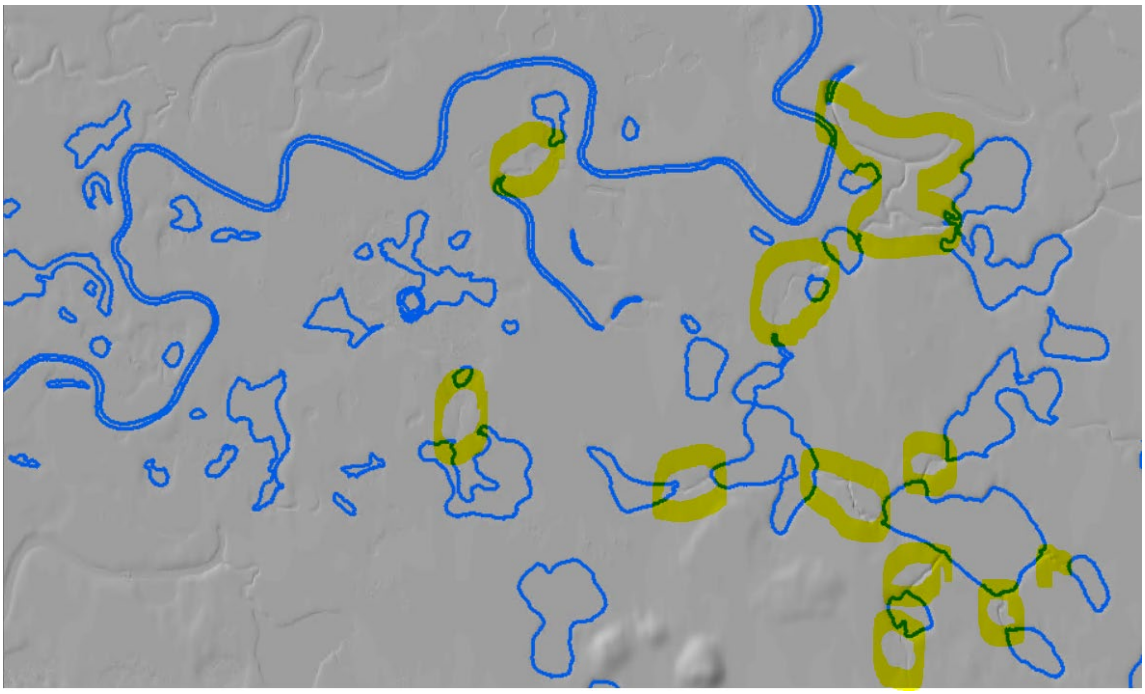
B. Areas which are filled (sinks removed) can be subtracted from the original surface. Depth to fill should be reviewed. Anything that is filled more than 2 meters to create flow would require considerable adjustment to the flowline in order to create flow out of the depression.
In this example, the areas in yellow and green require less than 2 meters of fill to create downhill flow. The areas in blue are more than 2 meters below the surface and would need to rise over 2 meters to flow downstream towards an outlet. The areas in blue are likely isolated features:



Consideration 2*: Identify channel locations on DEM, without the use of flow accumulation and flow direction models.*

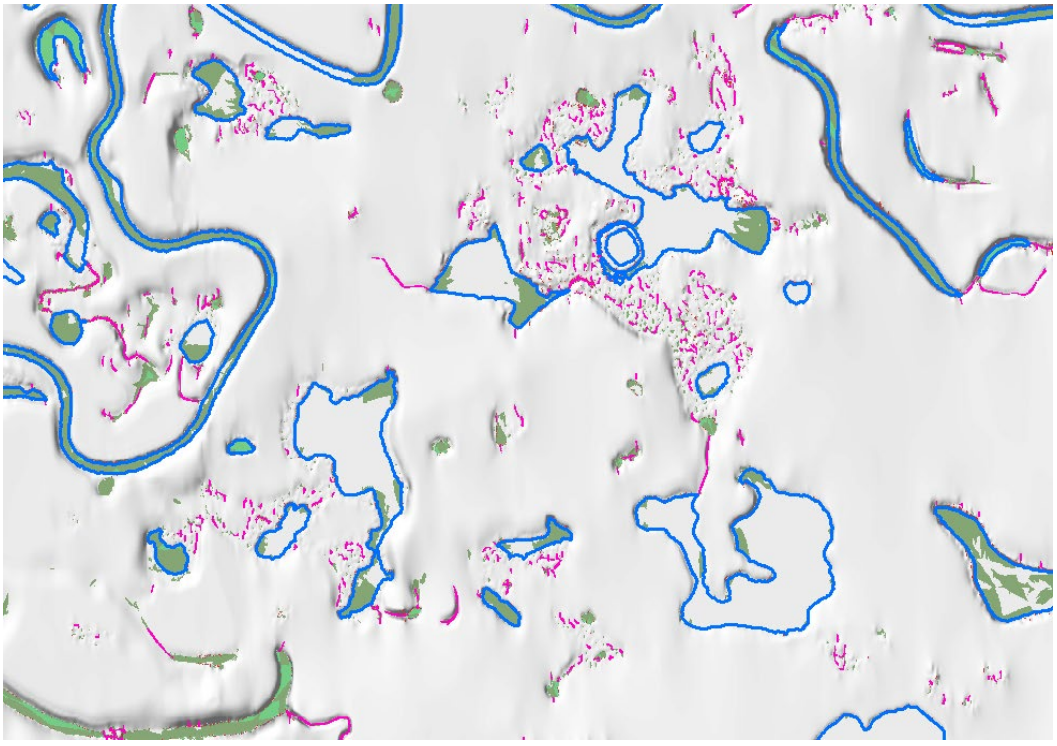
Identify channels to locate isolated features, and to identify channels that may be used in feature connectivity. Note that not all channels will need to be added if the features are within nested depressions.

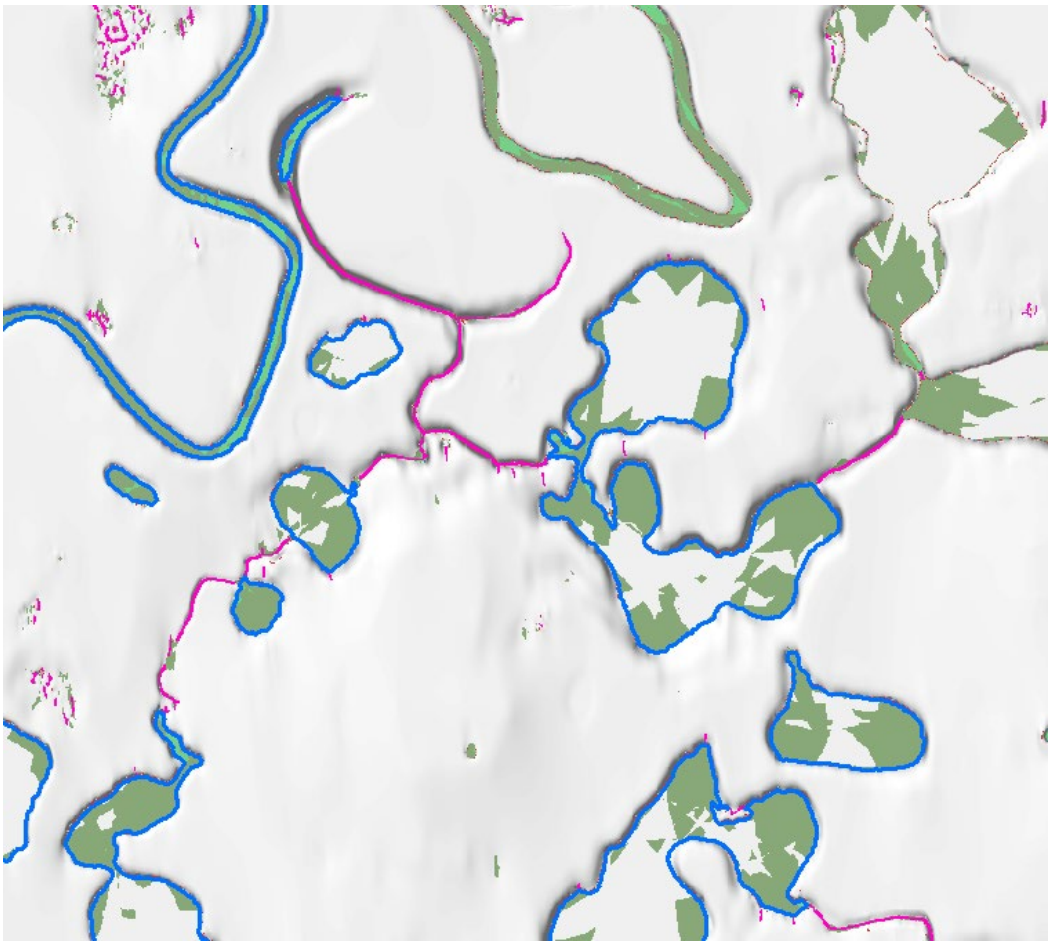
A. This example shows visibly identifiable channels with a simple hillshade:



B. Geomorphic derivatives may be used to identify a channel. In this example, channels were found using geomorphic derivatives that do not enforce flow. BotHat channels, curvature and geomorphons were run on the unaltered surface. The pink (BotHat channels, Red (curvature) and green (geomorphon valleys and depressions) indicate more natural connections between features.

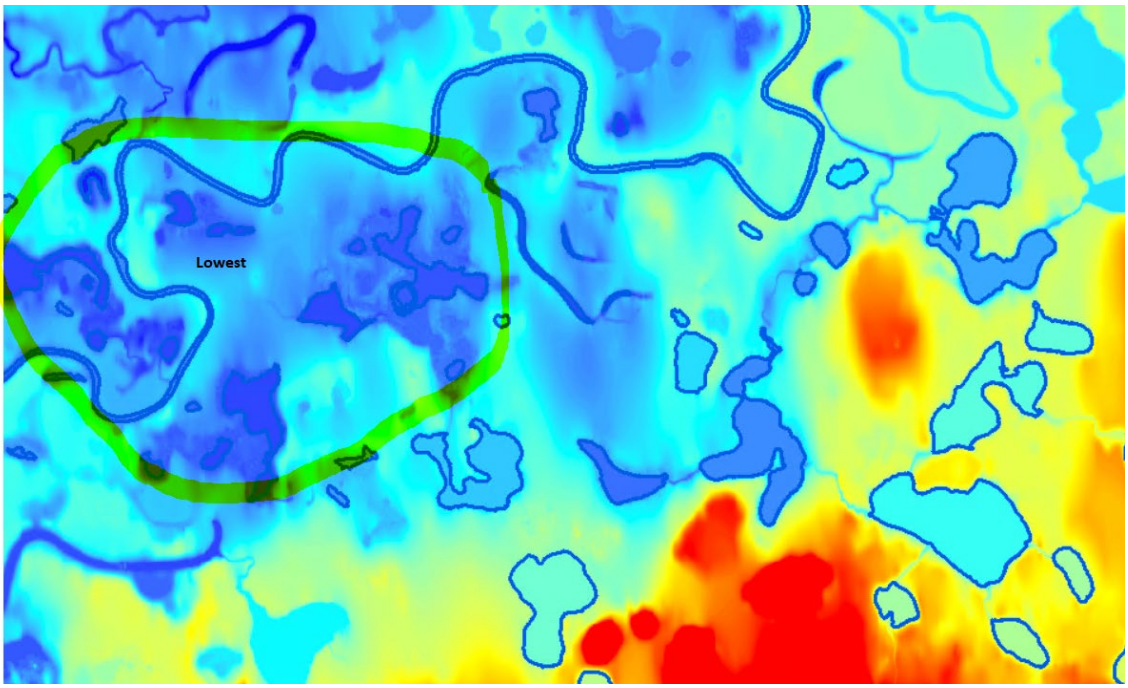
Two examples showing channel locations:



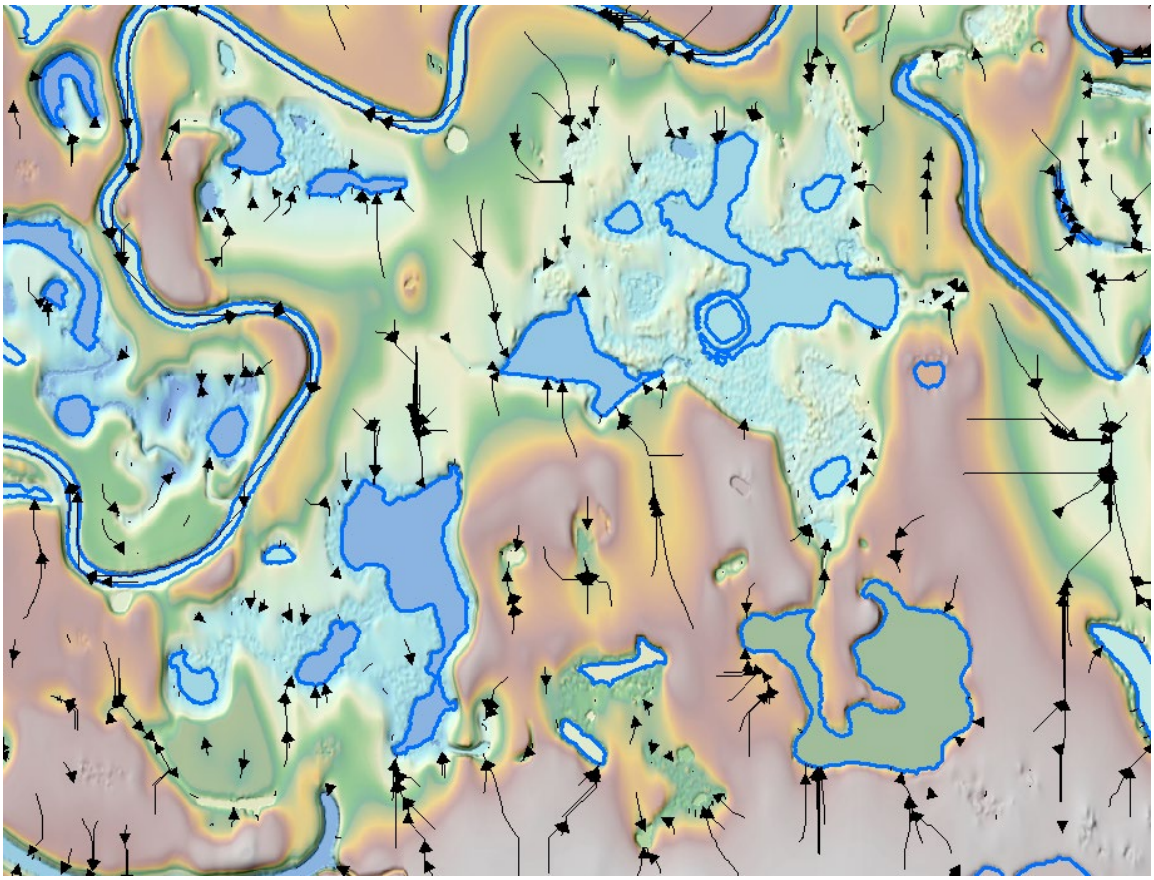


Consideration 3*: Find the lowest drainage areas to help determine flow direction for connectivity where it exists:*

A. Visually review area for general direction of flow from high to low elevation. Example showing the visually identifiable lowest areas on a DEM:

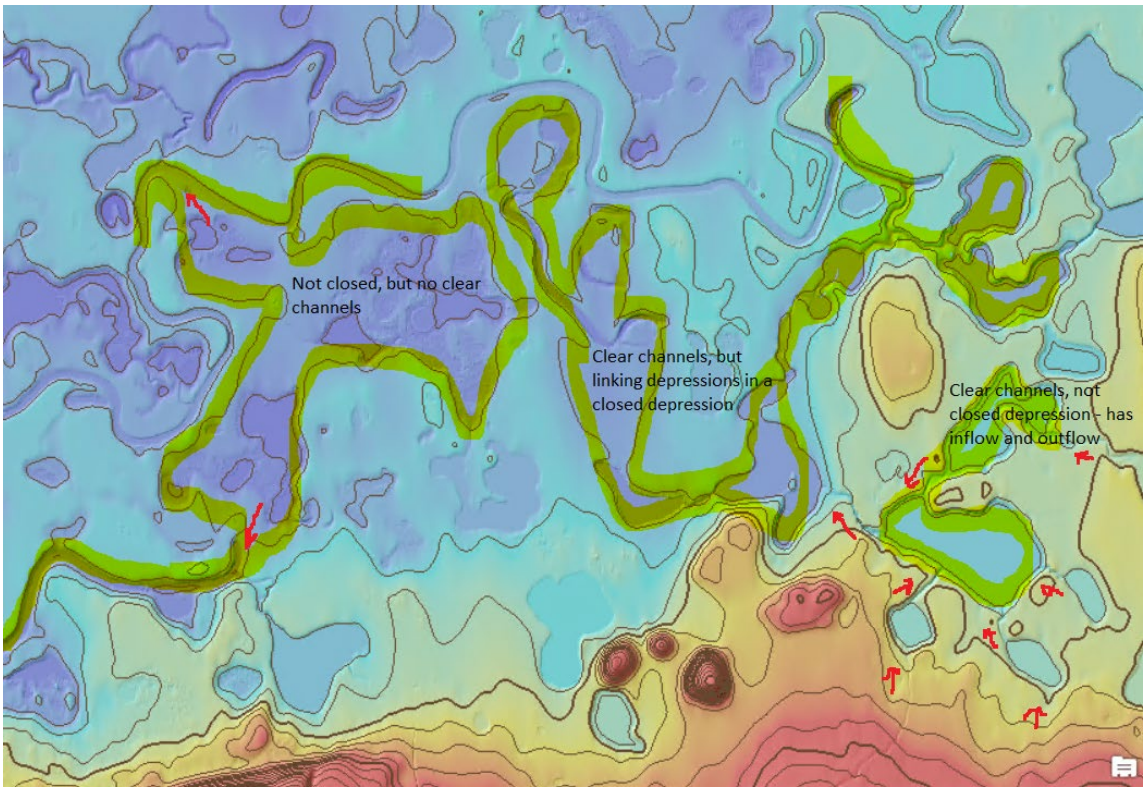


B. To understand general flow direction, a flow direction raster that is not hydro enforced (no fills) can be made. This will show the surface flow without forcing the flow to be connected throughout the watershed. Arrows show direction of flow based on elevation surface. Vectors of flow from multiple directions into depressions often indicate an isolated depression.

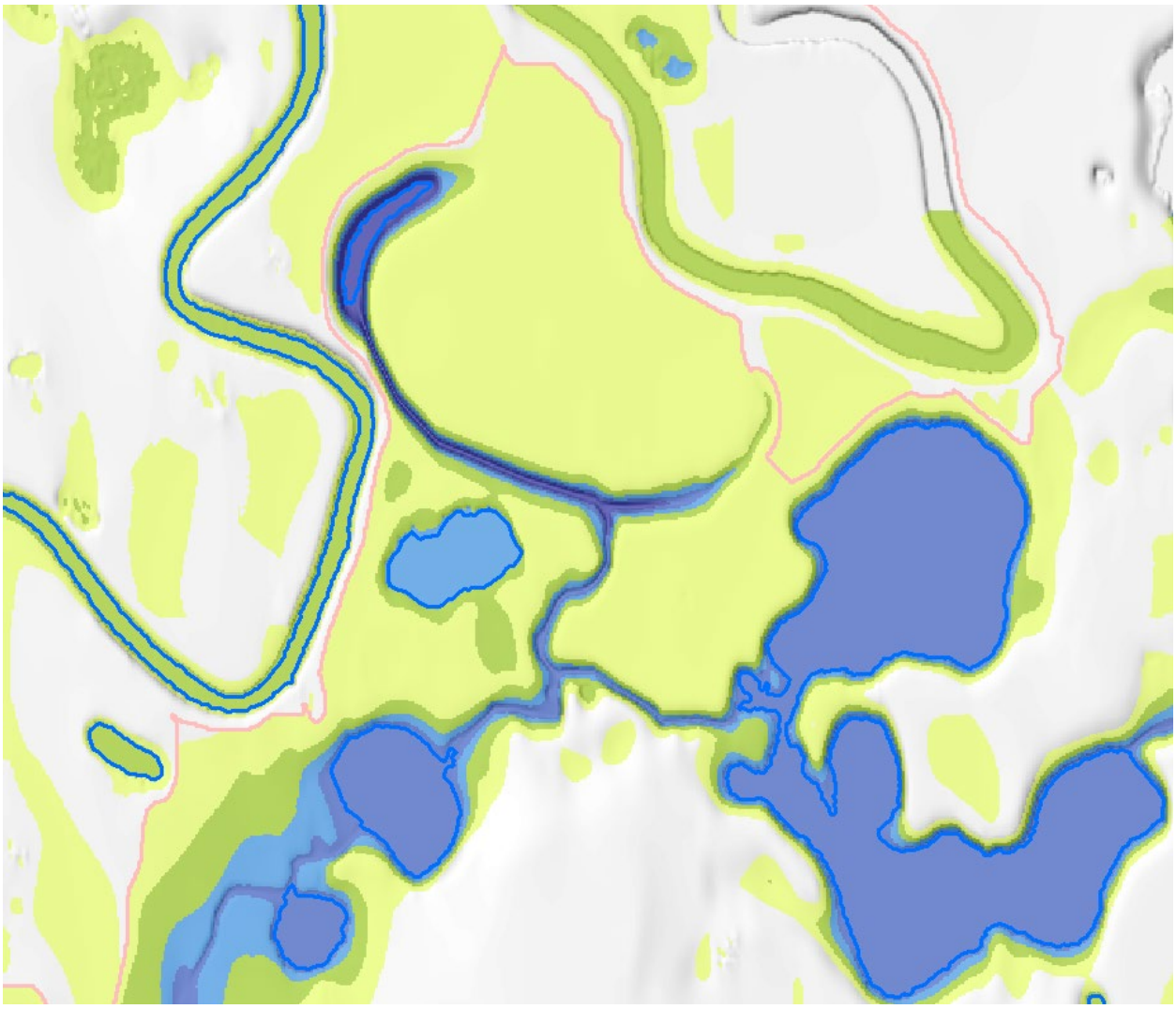


Consideration 4*: Identify depressions nested inside of closed depressions. These do not need to be connected even if there are clearly identifiable channels between the inner depressions:*

A. Contour lines can be used to help identify closed depressions:

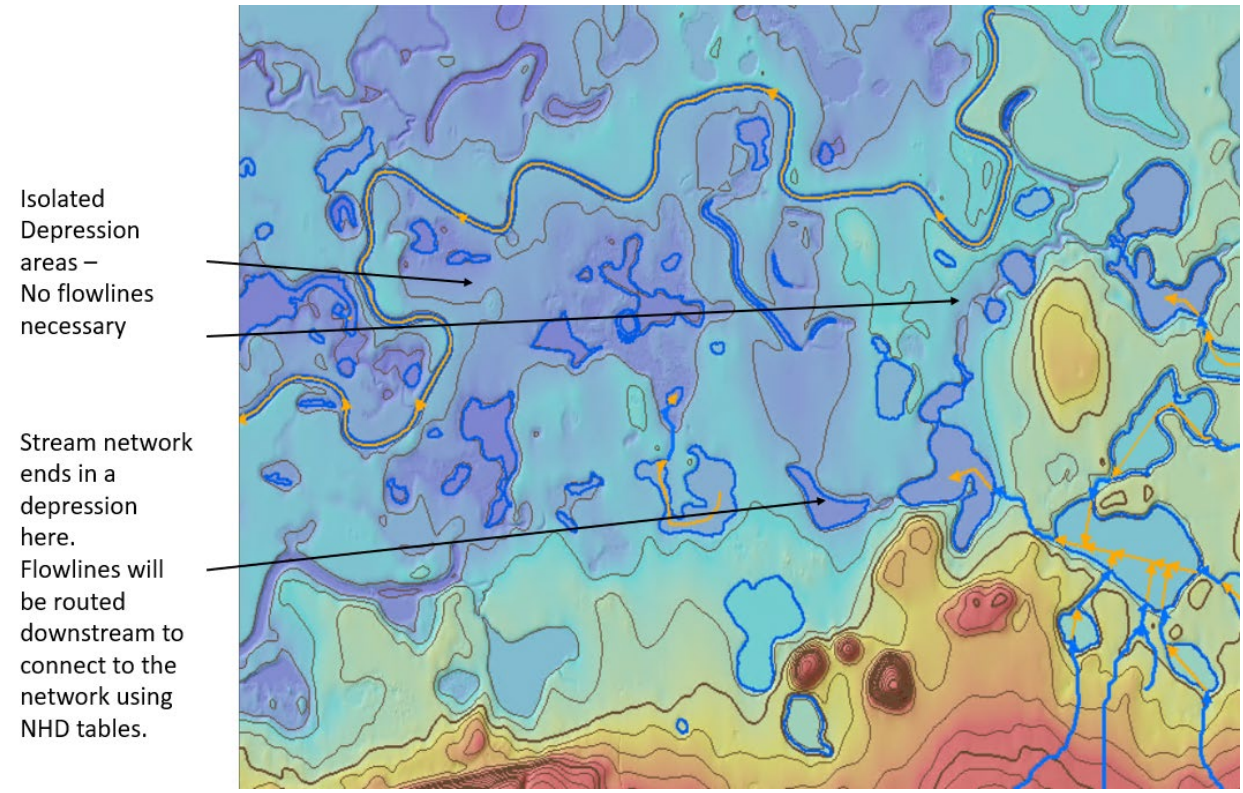


B. Delineating watersheds around the depressions can also help identify if there is connectivity out of the depression to a stream channel.



Final recommended connectivity and flow direction.

With apparent channels, lowest drainage areas, and closed depressions identified, approximate locations of flow directions and channel connections between features may be identified, considering the overall landscape flow direction (from south to north in this example area):



Example 2: Upstream headwater depression

Example showing a large headwater depression, which should be disconnected from the network. Recommendation: Disconnect headwater depression from network. Initiate stream network at natural watershed divide flowing away from the depression.