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# Use of Spatial Modelling to Select the Helicopter Landing Sites

V. Kovařík*

*Department of Military Geography and Meteorology, University of Defence, Brno, Czech Republic*

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**Abstract:**

*The paper describes a procedure of selecting areas potentially suitable for landing of particular formations of helicopters. It describes specific requirements of the NATO documents that have to be respected when selecting the areas for landing. These requirements relate to a slope of ground and an obstruction angle on approach and exit paths. It also lists natural and man-made terrain features that represent the obstacles that can prevent helicopters from landing. Creating the knowledge base and graphical models in ERDAS IMAGINE is then described. The results of modelling different configurations of landing points are presented.*

**Keywords:**

*ERDAS IMAGINE, helicopter landing sites, knowledge base, spatial modelling*

## 1. Introduction

The thematic maps and other geographic products showing locations suitable for landing of helicopters belong to common products within geospatial support of military, peacekeeping and other operations. They are also often produced within the process of the Intelligence Preparation of the Battlefield (IPB), especially during the second step of IPB which is focused on analysing the environmental effects and describing the effects on threat and friendly capabilities. Within this step, the conditions of ground forces activities are evaluated, taking into account natural obstacles [1, 2, 3] or considering various climatic conditions [4]. These analyses can be described using physical models of a movement of vehicles of different kinds in the terrain. The models can be mathematically processed and then transferred into computing environment [5, 6]. The analysis results are usually presented in the form

* *Corresponding author: Department of Military Geography and Meteorology, University of Defence, Kounicova 65, 662 10 Brno, Czech Republic, phone: +420 973 445 223, fax: +420 973 445 068, E-mail: vladimir.kovarik@unob.cz*

of digital thematic maps and other products and exploited in the command and control systems.

Production of these maps can be a lengthy process and requires verification in the terrain. When searching large areas, it can be convenient to predict where the suitable locations might be and also to reduce the number of places to be verified. This can be achieved by using applications such as the one described in this paper. These applications can be tailored specifically to particular types of helicopters and to their specific formations.

The paper describes an application employing spatial modelling for selecting locations that are suitable for landing of various helicopter formations. Still, such an application will always serve as an auxiliary tool supporting the decision where to land. The ultimate decision concerning a particular landing site depends on a current situation in the terrain.

## 2. Background

The problem of selecting locations suitable for landing can be divided into the two following parts: (1) selecting areas potentially suitable for landing of a helicopter and (2) searching for locations suitable for landing of particular formations of helicopters.

### *2.1. Selecting Areas Suitable for Landing*

To carry out an analysis of locations suitable for landing of a helicopter in a given area, both natural and man-made terrain features that can represent obstacles have to be determined [7]. There are features that can act as obstacles due to their height, such as forests, power lines, or communication towers. Other features can impede landing by their nature, such as lakes, swamps, or vineyards. All the features included in the analysis were classed to categories as follows:

- Vegetation: forest, wood strip, nursery, orchard, vineyards, hop-garden, reed-grass
- Water: lake, river, canal, ditch, swamp, aqueduct, water tower
- Transportation: road, railroad, aerial cableway
- Utilities: pipeline, power line
- Terrain: rocks, cliffs, crevasse, depression, fault, landslide, karst
- Built-up areas: settlement
- Other objects: chimney, cooling tower, power station, transformer yard, oil rig, tower, windmill, cemetery

There are other factors that should be considered when modelling the obstacles hindering the landing, such as the soils or surface materials, weather conditions, other types of vegetation, and so on. However, these factors were not considered during this stage of the works.

In addition, there are specific requirements, such as in the NATO Standardization Agreements (STANAG), ICAO (International Civil Aviation Organization) or national procedures for particular types of helicopter. These documents have to be taken into consideration when selecting the areas for landing. For the works described in this paper, the STANAG 2999 “Use of Helicopters in Land Operations Doctrine” setting criteria for selecting helicopter landing sites for day and night operations was used as a guideline [8]. This document does not specify the types or nature of the obstacles, but it describes the selecting criteria for locations suitable for tactical or non-permanent landing sites. From a variety of conditions only the following two conditions were selected for further analysis: (1) slope of ground and (2) obstruction angle on approach and exit paths. These criteria can be formulated as follows:

- Slope should not exceed 7° or 3° in any direction by day or night, respectively.
- Within the selected approach and exit paths, the maximum obstruction angle to obstacle should not exceed 6° to a distance of 500 m by day and 4° to a distance of 3000 m by night.

Fig. 1 shows a diagram explaining requirements of the STANAG 2999 for a maximum height of obstacles with respect to a distance from a landing point. It shows differences between day and night operations.

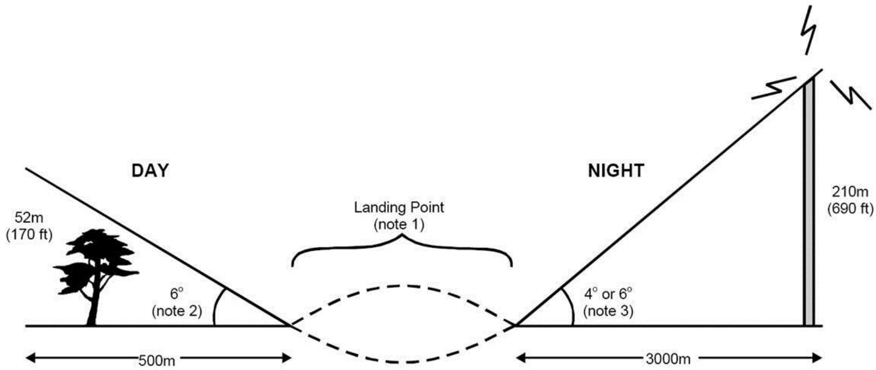


*Fig. 1 Landing point obstruction angle on approach and exit paths for day and night operations [8]*

### *2.2. Searching for Locations Suitable for Landing of Particular Formations*

Knowing all the areas suitable for landing with respect to natural and man-made obstacles and with respect to requirements for a slope of ground and for the maximum obstruction angle, searching for locations suitable for landing of particular helicopter formations can be started. It is not expected to search for locations allowing landing of a single helicopter. The geospatial data possessing sufficient spatial resolution, precision, and reliability enabling selecting such small sites will rarely be available in the operational reality. The geographic products showing the locations where a single helicopter can land do exist but these locations are usually selected using different method. They are pre-selected using the thorough knowledge of the particular area of the interest and then verified by a field inspection.

The landing sites are usually composed of several landing points having specific dimensions. The STANAG 2999 specifies the minimum dimensions for five sizes of landing points:

- Size 1: 25 m
- Size 2: 37 m
- Size 3: 50 m
- Size 4: 80 m
- Size 5: 100 m

The dimensions refer to the diameter of the circular landing points (the size 3, 4, and 5 landing points can be also rectangular). The whole landing point must be free of obstructions over 0.6 m, the surface of the centre of the landing point must be sufficiently firm to bear a fully loaded helicopter.

The size of the landing point that is finally selected is affected by numerous considerations, such as helicopter type, unit proficiency, nature of loads, climatic conditions and day or night operations. When these parameters are not known, the largest landing point size is chosen.

The number of landing points determines the size and the shape of the landing site that is searched for. Two, three, four, and five landing points were taken into consideration during the analysis. To find the smallest possible space where the indicated number of helicopters can land, various configurations of landing points can be considered. The areas suitable for landing can then be analysed with the aim of selecting locations where particular configurations of landing points in any position can fit.

Apart from finding locations matching particular shapes, sizes, and orientation of landing point configurations, various tactical tasks or requirements can be modelled. These can be requirements for a maximum distance between landing sites and roads; proximity to specific corridors, dead ground or areas of interest; avoidance of minefields; and so on.

## 3. Study Area and Data

The study area is the vicinity of the city of Kosovska Mitrovica located in the northern part of Kosovo. The size of the study area is 40 by 60 km with the UTM coordinates of the centre E=490,000 m and N=4,740,000 m.

The standard VMap 1 (Vector Map Level 1) and DTED 1 (Digital Terrain Elevation Data Level 1) databases were used.

The VMap 1 database contains digital geospatial data in a vector format with resolution, accuracy and level of generalization relating to the map scale of 1:250,000. Data is separated into the thematic levels including boundaries, elevation, hydrography, industry, physiography, population, transportation, utilities and vegetation. The data stored in the VPF (Vector Product Format) format were transformed into the shapefiles and finally into the raster IMG format.

Tab. 1 shows the features used as the input data for a knowledge base, the appropriate layers (POP - population, IND – industry, UTIL – utilities, TRANS – transportation, HYDRO – hydrology, VEG – vegetation), the feature class names (i.e. the shapefiles), and corresponding DIGEST (The Digital Geographic Information Exchange Standard) FACC (Feature and Attribute Coding Catalogue) codes.

The DTED 1 database provides a uniform latitude/longitude based matrix of terrain elevation values. These values are recorded approximately every 100 metres (for longitude from 0° up to 50° north or south the spacing is 3 by 3 arc seconds, for other areas the spacing is different). The elevation data were also transformed into the raster IMG format.

## 4. Method

The spatial modelling tools provided by ERDAS IMAGINE software suite were used. This software suite offers three different techniques of building the models: (1) creating the knowledge base using the Knowledge Engineer module, (2) creating the graphical models using the Model Maker module, or (3) creating the custom algorithms and script models directly in the Spatial Modeler Language (SML) [9]. In case of works presented in this paper a combination of a knowledge base and graphical models was used for the analysis of all areas potentially suitable for landing. Then a combination of graphical models and SML scripts was used for analysis of locations suitable for landing of various formations of helicopters.

*Tab. 1 List of features representing the obstacles*

| **Layer** | **Feature name** | **Feature class** | **f_code** |
|---|---|---|---|
| POP | Built-up area<br>Settlement | builtupa<br>mispopa | AL020<br>AL105 |
| IND | Chimney/Smokestack<br>Tower | obstrp<br>towerp | AF010<br>AL240 |
| UTIL | Communication tower<br>Power transmission line | commp<br>powerl | AT080<br>AT030 |
| TRANS | Railroad<br>Road | railrdl<br>roadl | AN010<br>AP030 |
| HYDRO | Lake/Pond<br>Reservoir<br>River/Stream | lakeresa<br><br>watrcrsa<br>watrcrsl | BH080<br>BH130<br>BH140 |
| VEG | Trees | treesa | EC030 |

### *4.1. Selecting Areas Suitable for Landing*

Firstly, the hypotheses were formulated for creating the information classes representing parts of the terrain that are not suitable for landing due to a slope of ground exceeding the requirements of STANAG 2999, separately for day and night operations. Then the hypotheses were defined for creating the information classes representing either individual obstacles shown in Table 1 or certain groups of obstacles of a similar type. Within all these hypotheses the rules for selecting and visualizing of obstacles were created. The Fig. 2 shows the detail of a knowledge base. The hypotheses are depicted on the left, the rules are in the middle, and the variables are on the right.

Some hypotheses relate to the terrain features impeding landing by their nature, such as all water features, swamps, vineyards, railroads, etc. Other hypotheses create the information classes representing the buffer zones around certain obstacles so as to meet the requirement of STANAG 2999 for the maximum obstruction angle within the approach and exit paths. The sizes of these buffer zones vary according to the heights of the obstacles that enter the computation directly from the attributes of the shapefiles.

However, there are features in the data without a known height value. In those cases an average value of their height was used, for example 30 metres for forests, 6 metres for hop-gardens, 3 metres for orchards, and so on. Even the height of 2 metres for vineyards is significant because the width of a corresponding buffer zone is 19 metres for day operations and 29 metres for night operations.

The buffer zones were generated also for roads and railroads. The average height of 10 metres was set for roads because there are usually trees along these features. The same height was set for railroads as well because most of railroads are electrified.

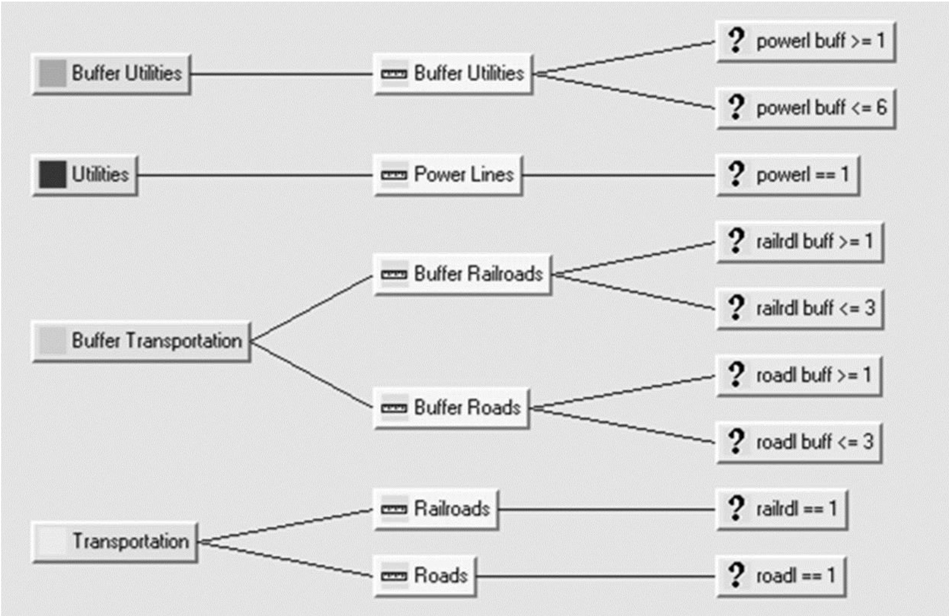


*Fig. 2 Portion of a knowledge base for selecting areas suitable for landing of helicopters*

In case of settlements the outlines only were used and no buffer zones were generated.

The output for the Built-Up Area hypothesis is an example of an individual obstacle. The output for the Water hypothesis comprising lakes, ponds, rivers, streams, canals, ditches and reservoirs is an example of the obstacle group. The outputs for the Forest hypothesis or the Power Line hypothesis are the examples of obstacles with buffer zones. The results of all hypotheses were then combined in order to obtain the overall layer showing those parts of the terrain not suitable to be considered as the landing sites. The requirements for day operations only were taken into considerations.

In case of specific requirements driven by a particular situation, some hypotheses can be eliminated. Also when a strict requirement concerning a specific location is presented, then no analysis is needed and the terminal responsibility for landing lies on a helicopter pilot.

### *4.2. Searching for Locations Suitable for Landing of Particular Formations*

The functions based on eliminating small clumps of pixels, such as the CLUMP and SIEVE functions, are not suitable for the task described in this paper. That would find locations satisfying the requirement for a number of pixels only, which would not be correct. The functions working with convolution kernels had to be used.

Prior to searching, a total of eight landing point configurations were created. They were labelled accordingly to their shapes: I for two landing points; I and A for three landing points; I and O for four landing points; and finally I, H and W for five landing points (Fig. 3).

The convolution kernels of these shapes were created and then applied in the neighbourhood analysis to the layer resulting from the previous step. The FOCAL

SUM function returning sum of pixels in a convolution kernel around each pixel of the layer mentioned above was applied. If the sum equalled the pre-defined value, the current position of the convolution kernel was recorded. That meant one position of a particular landing point configuration that complied with the requirements for landing. All eight kernels were applied and corresponding results for the whole study area were generated. The example of a portion of a graphical model searching for locations suitable for landing of four helicopters is shown in Fig. 4.

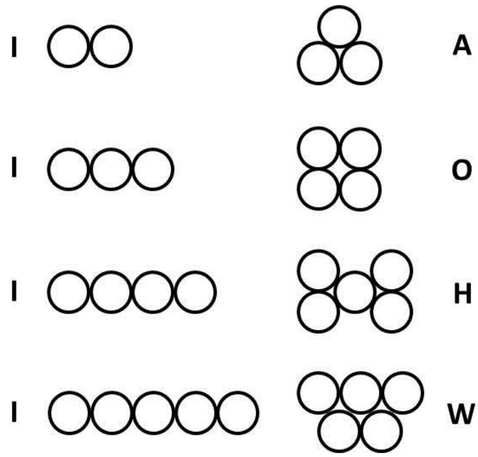


*Fig. 3 Configurations of landing points for two, three, four, and five helicopters*

Finally, the two tactical requirements were added: (1) the maximum distance of 200 metres between landing sites and roads for the purpose of loading and unloading by vehicles, and (2) an exact position of the specified area of interest that was represented by a given overlay. That has further reduced the number of potential landing sites that would be necessary to verify in the terrain.

## 5. Results and Discussion

From all possible combinations of data processing only the day operations requirements and the default size of landing point, i.e. the size 5, were considered in computations. The flowchart showing the procedure of data processing is shown in Fig. 5. However, the models created in this work allow generating varied outputs considering both day and night operation requirements and all the landing point sizes depending on the helicopter types that would be used in a particular operation.

The results for landing of two, three, four, and five helicopters were generated and compared. As it was expected, when searching for landing sites comprising more landing points, fewer locations within the study area were selected. The examples of results of locations complying with requirements for landing in Fig. 6: the outputs of selected hypotheses (upper left), locations suitable for landing generally (upper centre), locations suitable for landing of two (upper right), three (lower left), and four (lower centre) helicopters, locations suitable for landing of four helicopters considering selected tactical requirements (lower right) – suitable locations are depicted in white.

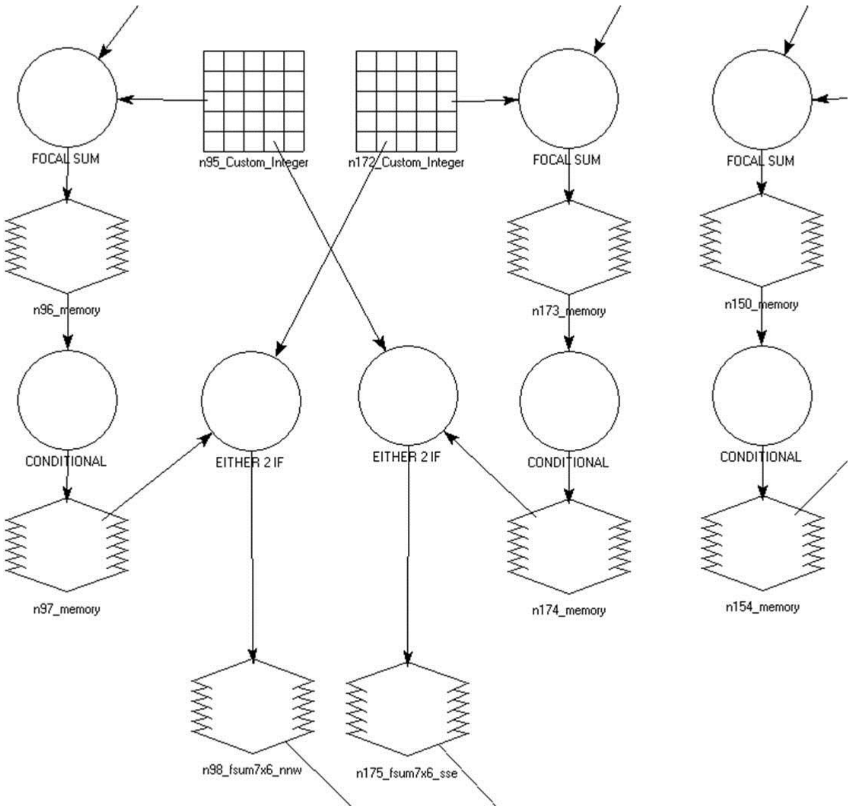


*Fig. 4 Example of a graphical model*

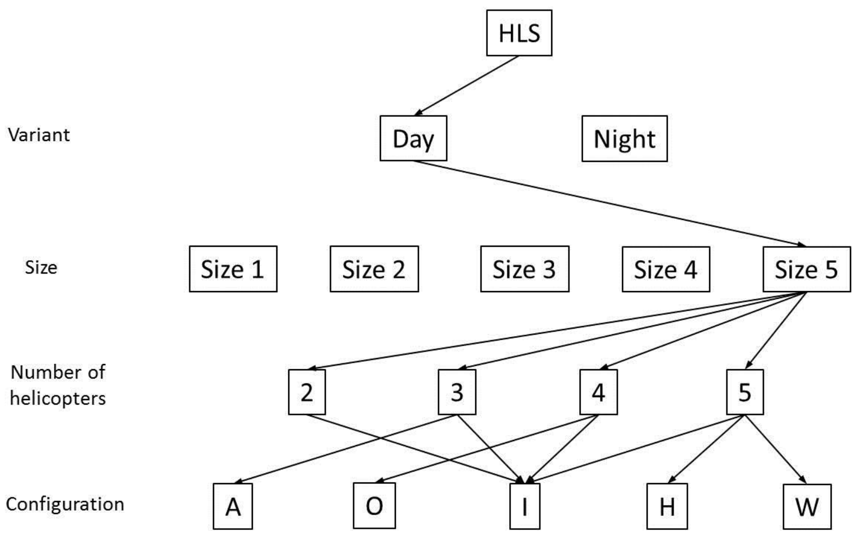


*Fig. 5 Flowchart showing the procedure of data processing undertaken in this study*

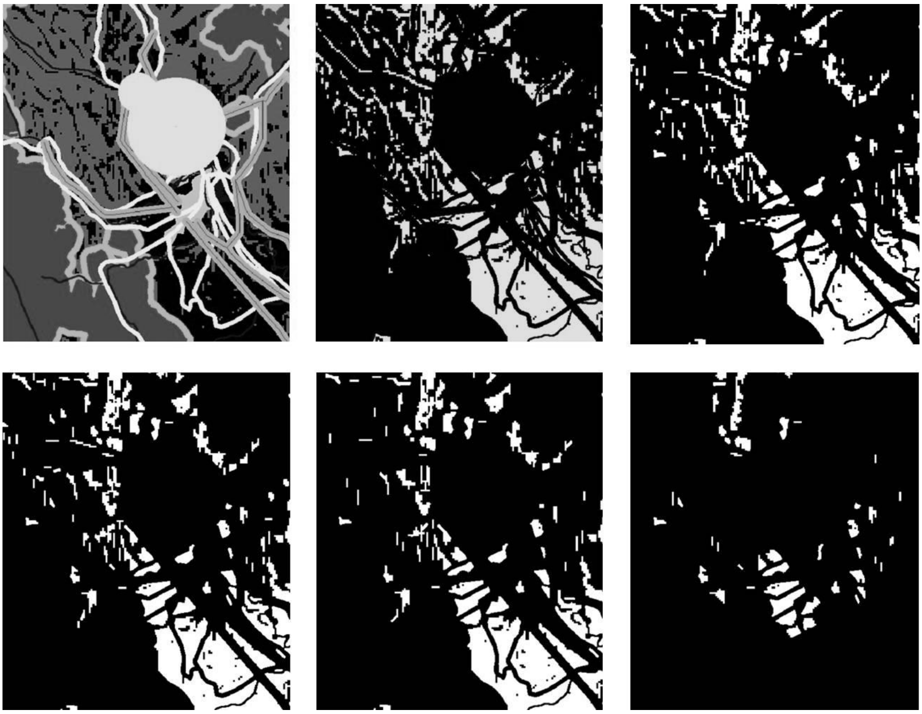

*Fig. 6 Examples of results showing locations suitable for landing (suitable locations are depicted in white).*

Because the problem of modelling conditions for selection of helicopter landing sites is relatively complex, certain simplifications were adopted in this phase of a project. For example, instead of the real width of linear features (roads, railroads, rivers, power lines, etc.) their centre lines were considered only; the heights of certain obstacles did not enter the computation automatically from the attributes (e.g. orchards, vineyards, wood strips, nurseries, etc.), but they were set ad hoc within the scripts; all directions to the landing sites were considered as the approach paths, so as the same criteria for an obstruction angle could be employed in all cases; positional errors of buffer zones caused by potential inaccuracies in the feature heights were not considered; a combined effect of a soil type and weather information was not considered; etc.

The experience from this phase of the work can be used for refining both the knowledge base and the models. The results described in this paper were not verified in the terrain yet, because it was not the aim of the study. However, testing using different datasets covering various landscape types should be performed in the following phases of the work.

Apart from the field inspection, there are other methods that can be used for verification of the results of modelling. For example, it is possible to use the tools of constructive simulation with a different aggregation level [10]. This method is often used during the preparation of the staffs before their deployment to the operations.

## 6. Conclusions

It is necessary to emphasize that whatever accuracy and reliability of the knowledge base and the models can be reached, this method will always be an auxiliary planning tool only. It will always depend on accuracy and reliability of the datasets and it can never portray the real situation in the terrain. The local conditions, such as snow, sand, dust, vegetation, etc. are very difficult to predict. The application described in this paper can help to find and pre-select locations suitable for landing, especially in the planning phase of the operations, but it has to be always followed by verification in the terrain. Only after that the locations can be included into the list of the helicopter landing sites and be depicted in associated geographic products.

The ultimate decision whether or not and where to land will always rest with a helicopter commander or a formation leader. However, the results of this method can reduce significantly the extent of the area to be searched for landing sites. It can be used for generating the products showing the locations suitable for landing of specific helicopter types in day or night operations and for a given number of helicopters. Also specific tactical tasks can be included into the solution.

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