4 Decision support system factors

4.1 Introduction to Decision Support Systems

The concept of a decision support system (DSS) is a very broad and depends solely on the interpretation of the author (Druzdzel & Flynn, 1999). According to Carsjens (2009) decision support systems are dynamic and interactive process based systems that aim to enhance a person or group's ability to make decisions. These systems are especially relevant in complex situations and poorly structured decision problems. They put forward the possibility of conceptualizing or dealing with the entire problem as a whole, and in doing so, reducing the uncertainties in the decision making process (Sojda, 2007). Druzdzel and Flynn (2002) also support this by stating that decisions regarding complex systems are simplified by compiling a complete picture of the related decisions by including all the possible alternatives. According to Arnott (1998), DSS are not only evaluation systems, but may rather be seen as 'adaptive' and 'evolutionary' systems that may evolve over a series of development cycles in which the shape, nature and logic of the system are defined and redefined.

Decision support systems may therefore be defined as decision-making tools based on evaluation of a set of parameters in a linear process based on inputs with certain conditions towards an output. This should contribute to reducing the uncertainty faced by managers when they need to make decisions regarding future options (Graham and Jones, 1988). Alignment and integration of decisions between various entities and systems are enhanced with parallel decision support systems. A DSS is considered essential in various disciplines, specifically in the geo-environmental field (Sanchez-Marre *et al.,* 2008).

This section will explore the origin, processes and attributes related to DSS in developing a geo-environmental DSS for development on dolomite.

4.2 Origin of DSS's

The concept of decision support has evolved from two main research areas: 1) Theoretical studies of organizational decision making done at the Carnegie Institute of Technology during the late 1950s and early 1960s, and 2) The technical work on interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s (Keen & Scott-Morton, 1978). These systems where initially developed for the business environment, focusing on production, promotion, pricing, marketing and some logistical functions. This evolved into an academic system in the 1980s, which paved the way for complex DSS being developed in the 1990s (Louw, 2002). It became clear that DSS's belong to an environment with multidisciplinary foundations, including (but not exclusively) database research, artificial intelligence, human-computer interaction, simulation methods, software engineering, and telecommunications (Power, 2002).

4.3 Introduction to Environmental DSS

The development of environmental decision support systems (EDSS) depend on the type and amount of information that is available. Due to the nature and extent of the effect of environmental based decisions, EDSS's must inform those who are affected by the decisions (Sanchez-Marre, *et al.,* 2008). Even though an environmental DSS may be considered a generic decision-making tool, detail and specific knowledge of each of the inputs and parameters is still required. This implies a problem awareness that in turn must be based on information, experience and knowledge about the process. These environmental systems are built by integrating several artificial intelligence methods, geographical information system components, mathematical or statistical techniques, environmental technologies, some minor economic components as well as geo-environmental data and information sources (Dorner *et a1*., 2007; Reichert *et al*., 2007; Cortes *et al*., 2002). This process of evaluation of the available information may be represented as in Figure 13:

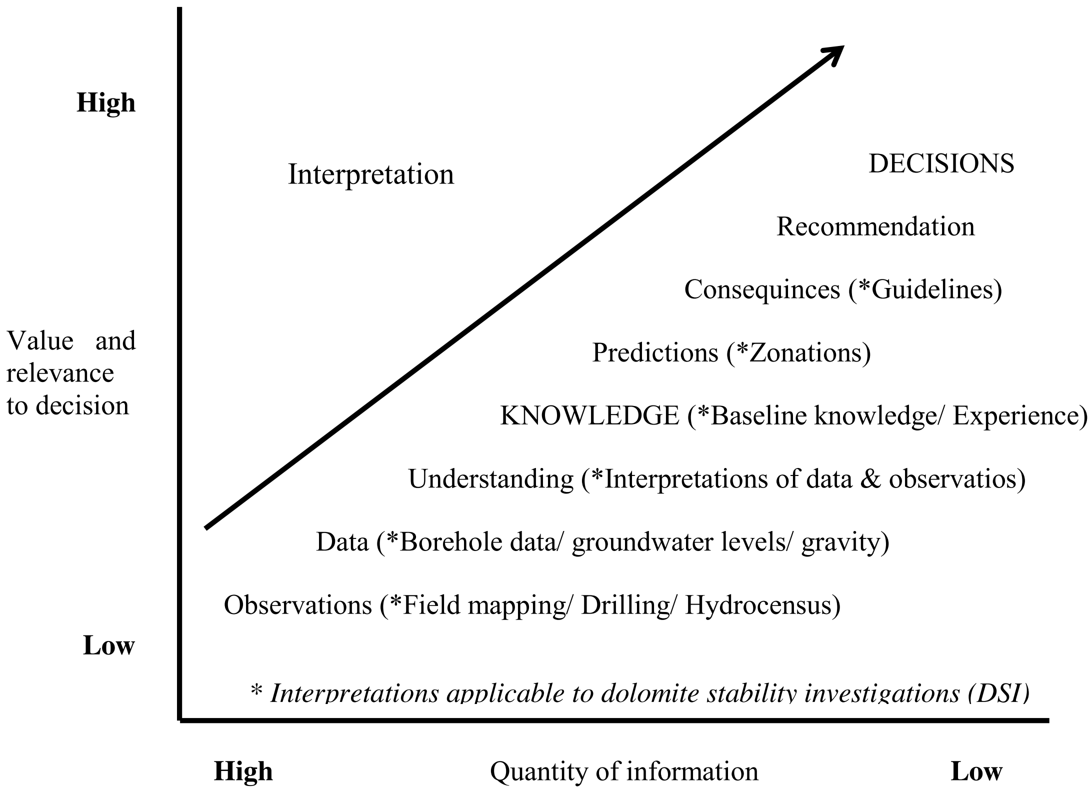


Figure 13: Interpretation Process of Information

Source: Adapted from Wittaker, 1993

4.4 Development of DSS's

The development of a DSS as previously mentioned is an evolutionary and adaptive process. In applications where the outcomes of a project or situation may affect the lives and livelihood of an entire community, it is regarded as high priority to evaluate all decisions made based on a DSS due to the transparency and consistency of the system. DSS's must therefore be scrutinized throughout the development process. Sanchez-Marre, *et al*. (2008) propose the following four problems which must be evaluated when developing a DSS: 1) uncertainty of the data, 2) spatial reasoning, 3) temporal reasoning and 4) reliability of the decisions proposed. Figure 13 is a schematic flow diagram of the proposed development of a DSS:

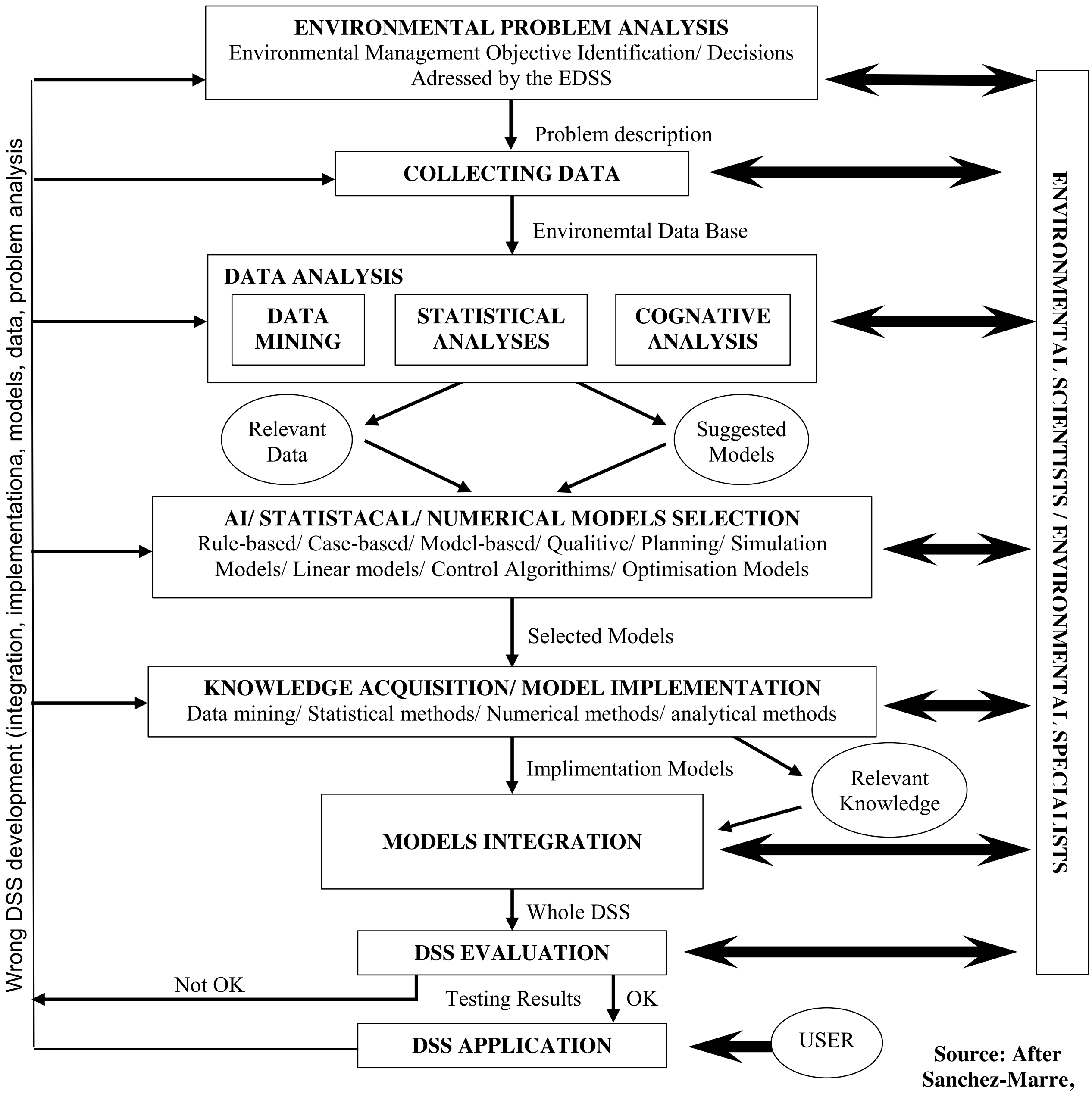


Figure 14: Flow Diagram for development of a DSS

Source: After Sanchez-Marre, *et al.* (2008)

The basic architectural components of a DSS are the database management system (DBMS), the modeling system and the user interface system (Carsjens, 2009). These may be interpreted as the data based inputs (from the database), the model system or evaluation parameters and the outcomes/ outputs related to the end user by means of a user interface.

Figure 15 broadly outlines the specific components as described above:

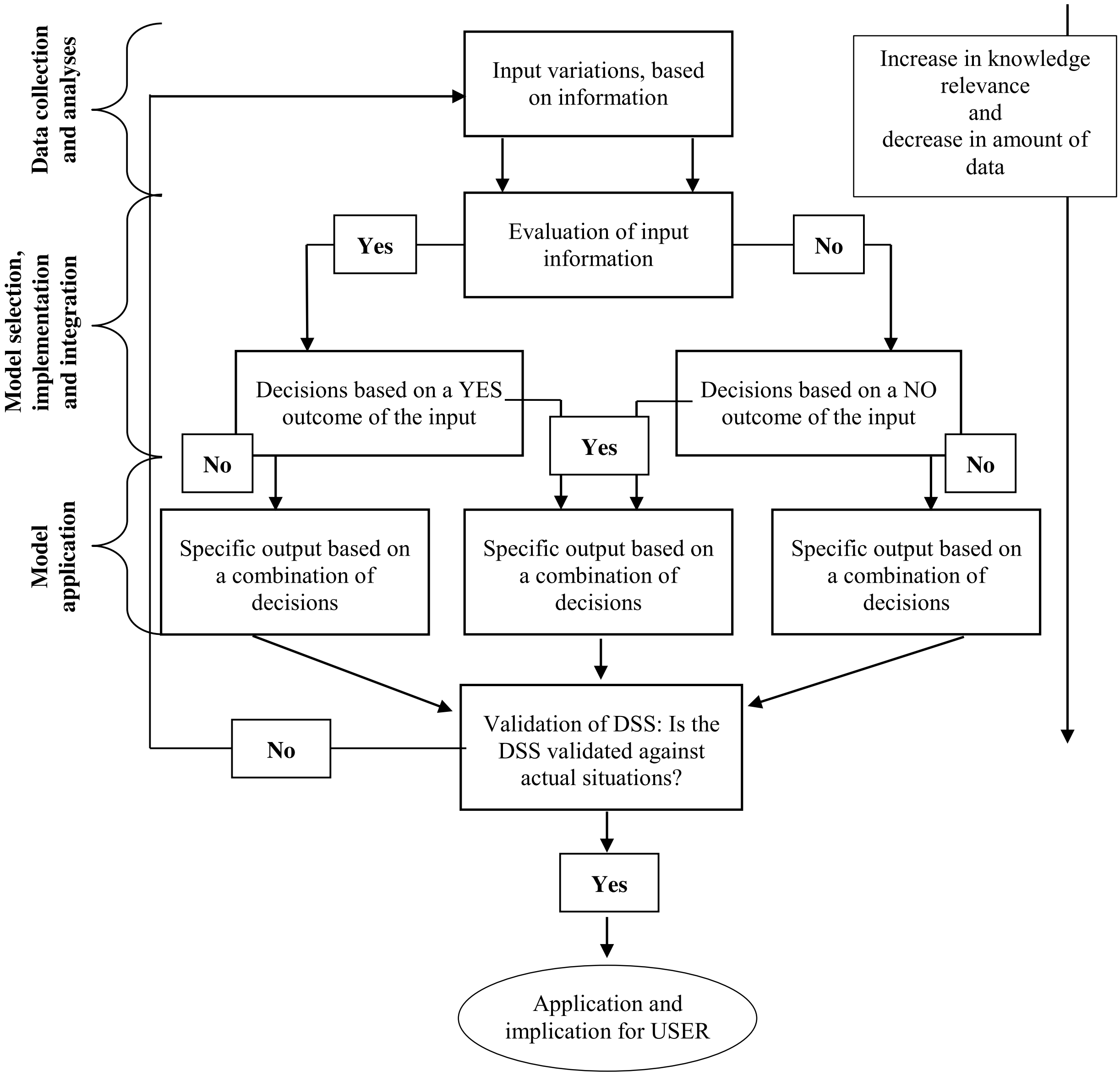


Figure 15: A DSS breakdown

Source: Own creation (2012)

Based on Figures 15, 16 and 17, the following observations may be made:

- A single decision will not determine the immediate outcome if evaluated in conjunction with the entire DSS;
- Various combinations of decisions may lead to the same outcome;

- "No" and "yes" decisions for different scenarios may result in the same outcome;
- The amount of inputs and decisions in the DSS may be refined and this may result in a lower number of outcomes;
- An increase in amount of information does not necessarily lead to better decision making.

4.5 Development of a DSS for Dolomite Stability Investigations

In the following section, the input parameters, evaluation criteria and possible outcomes of a DSS for a dolomite stability investigation will be proposed. This will be based on the outline of a DSI as proposed in section 2.8 of this document, and as implemented in section 3 of this document. This is based on site-specific parameters and may include other parameters based on the site conditions.

4.5.1 Input parameters

The following input parameters need to be included in the DSS:

Geo-environmental site conditions:

- Drainage
- Topography
- Geophysical conditions
- Regional geological conditions
- Local geological conditions
- Regional groundwater conditions
- Local groundwater conditions

Geotechnical stability of the dolomite based on the hazard characterisation and evaluation procedures:

- Percussion drilling data
- Receptacle development
- Mobilisation agencies
- Potential surface manifestation development space
- Nature and mobilisation potential of the blanketing layer
- The bedrock morphology

4.5.2 Related processes and outcomes

The process of evaluation is to culminate all inputs and processes into a final risk zoning of a certain area. This final recommendation may be presented as a spatial representation of the process as described above, but is formed and developed by means of a system of processes and decisions. Therefore each of the components listed above must be considered in terms of the contribution to the integrated representation and the total risk. The process therefore needs to determine whether a certain condition must be considered, and if it is to be considered, what the purpose and extent of the contribution may be. This may also be seen as the total contribution of the input to the risk and what the extent of the contribution is. These parameters are subdivided into the geo-environmental site conditions and the geotechnical conditions of the site:

Geo-environmental site conditions:

- Drainage – As described in section 3.6.4 of this document, ponding of water is a major cause of sinkhole formation. A poorly drained area will therefore contribute more to the total risk of an area than will an area which is well drained. The natural drainage patterns are also important in considering new development so as not to disturb the natural surface water drainage patterns, as this may contribute to sinkhole formation (Venter, 2005). The surface water drainage must also be considered and included in the evaluation of the groundwater conditions.
- Topography – The topography is a very good indication of the subsurface condition. An area where karst features, such as subsidence depressions, sinkholes and karst landscapes have developed, will need to be approached differently than areas with a normal topography.
- Geophysical conditions (gravity analyses) –The gravity anomalies of an area may be indicative of the solid dolomite bedrock topography and the possible thickness and density of the overburden (Trollip, 2007). It is very important to identify the gravity highs, gravity lows and the gravity gradients and then to investigate these anomalies further by means of geotechnical percussion drilling.
- Regional geological conditions – Section 2.3 of this document gives a comprehensive account of the distribution of dolomite within South Africa. As part of this evaluation the stratigraphy plays an important role, as well as the general characterises, content and structures of the regional geology. This is described in section 3.4.1 of this document.
- Local geological conditions – As described in section 3.4.3 of this document, the local geological setting of a site is very important. On a local scale, the type of geology must first be determined, including local geological structures and features including faults and

fractures (50 m development buffer if in dolomite (Buttrick, 2012)) and the strike and dip. This will later be used to interpolate the possible dolomite depth below ground level.

- Regional groundwater conditions – The regional groundwater tendencies may give a representation of the local geohydrological regime of the site. This may be used to correlate the original and current groundwater levels. This may be used to identify any possible groundwater level drawdown.
- Local groundwater conditions – The local groundwater levels are firstly necessary to evaluate the monitoring information and to develop trends with time. After drilling of the geotechnical boreholes, the water levels must furthermore be compared to the cavity levels to determine the risk related to the cavities. Where the groundwater level is below the upper surface of the cavity, the subsurface profile may be subjected to higher amounts of water ingress and mobilisation of the overlying material into the exposed cavity.

Geotechnical stability of the dolomite based on the hazard characterisation and evaluation procedures as described in section 2.7.6. These parameters are all based on and evaluated against the data gathered during drilling of the percussion boreholes:

- Receptacle development – The receptacle development is based on the possible size of the receptacle, penetration rates, air loss, sample recovery and hammer tempo. These components need to be evaluated in conjunction and comparison with each other.
- Mobilisation agencies – All potential mobilisation agencies need to be identified. This may include, but not be limited to, water ingress from ponding of surface water, water ingress from leaking infrastructure and water bearing features such as ponds and swimming pools
- Potential surface manifestation development space – The potential surface manifestation development space is a scientific hypothetical risk quantification process based on the drilling data, such as the thickness of the layer, the possible depth of the cavities below the surface, the estimated angle of draw and the possible size of the feature. This method is discussed in detail by Buttrick *et al*. (2001).
- Nature and mobilisation potential of the blanketing layer – This is based on a detailed evaluation of the vertical profile of each borehole and the intercepted material. This may include evaluation of the overburden material – material permeability, cohesiveness, clay/ sand content, hardness, consistency, mineralogical composition, fragmentation of the rock and grading of the material.
- The bedrock morphology – The bedrock morphology is based on identification and evaluation of sudden variations in the bedrock topography and the content and material type of the bedrock.

4.5.3 *Final DSI DSS*

From the complexity of the above-mentioned criteria, it is evident that a single DSS will not be sufficient in evaluation of sites underlain by dolomite. It is therefore proposed that the DSS for the DSI be split into two main DSS evaluation frameworks. The subcomponents of these frameworks may be interdependent and related to one another.

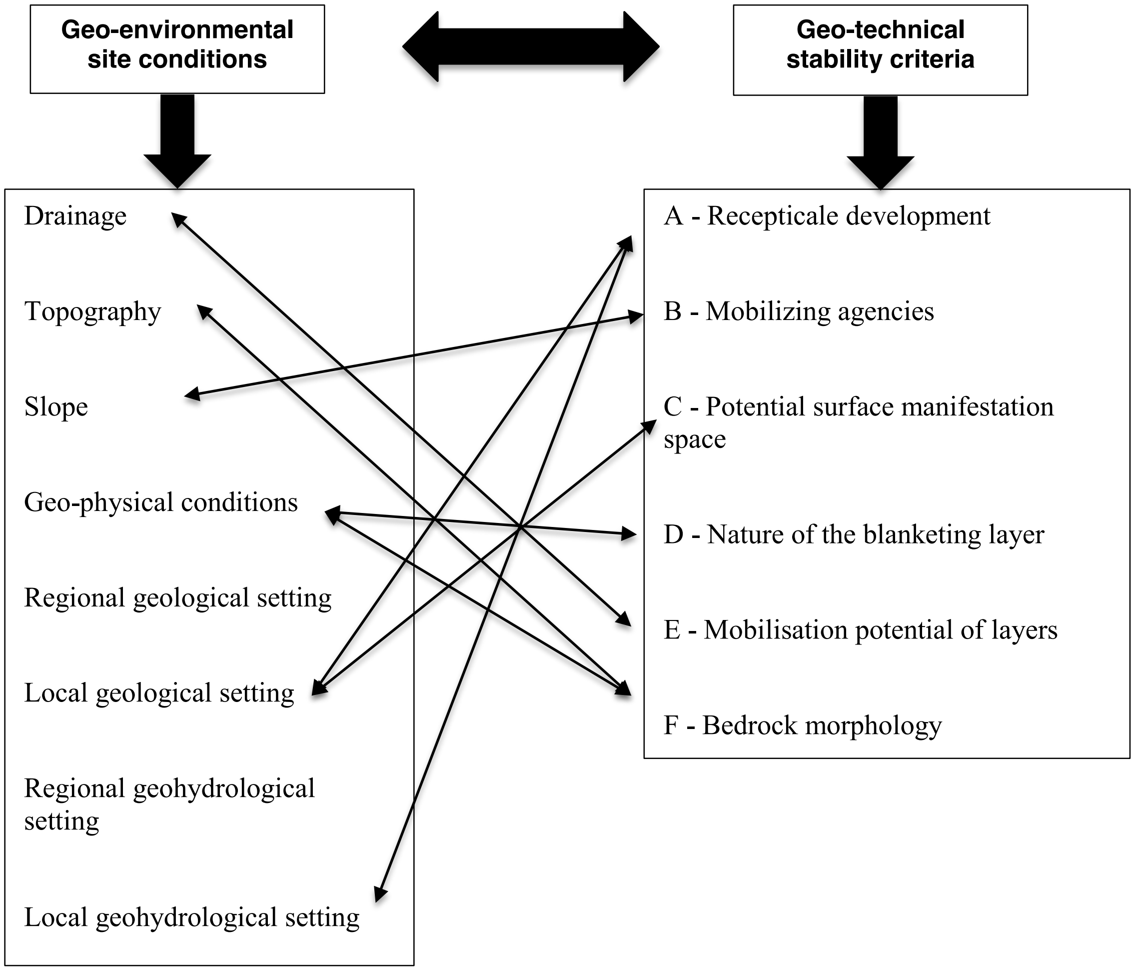


Figure 16: Framework to the final DSI DSS

Source: Own Creation (2012)

It is important to note that the development a DSS is based on the site-specific parameters of each individual site, and may therefore be different from site to site.

The correlations identified in Figure 16 are merely a theoretical implication of the possible variations that occur. The final DSS for the implementation of a DSI will include these correlations as well as the parameters of each process. Throughout the process of DSS development, it is at all times essential to keep in mind the outcome expected and the answers necessary.

The geo-environmental DSS for evaluation of the DSI results that contribute to development risk is based on the following criteria:

1 – Drainage, Topography and Slope

2 – Regional geological setting

3 – Regional geohydrological condition

4 – Local geological setting

5 – Local geohydrological setting

Based on the outcome of the geo-environmental DSS as described above, the geotechnical DSS for evaluation of the DSI results is composed out of the following criteria:

1 - Percussion drilling data

2 - Receptacle development

3 - Mobilisation agencies

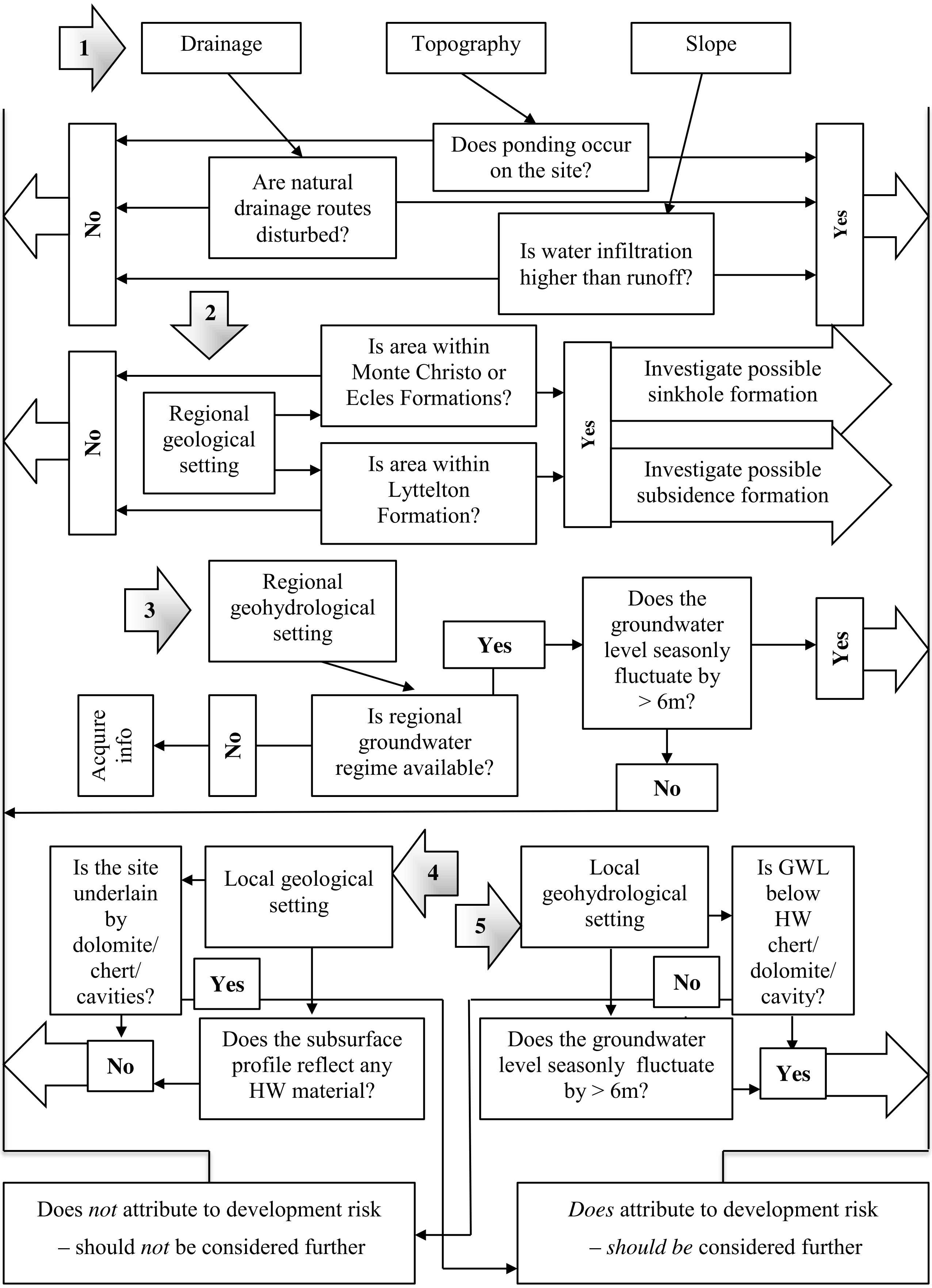
4 - Nature and mobilisation potential of the blanketing layer

5 - Potential surface manifestation development space

6 - The bedrock morphology

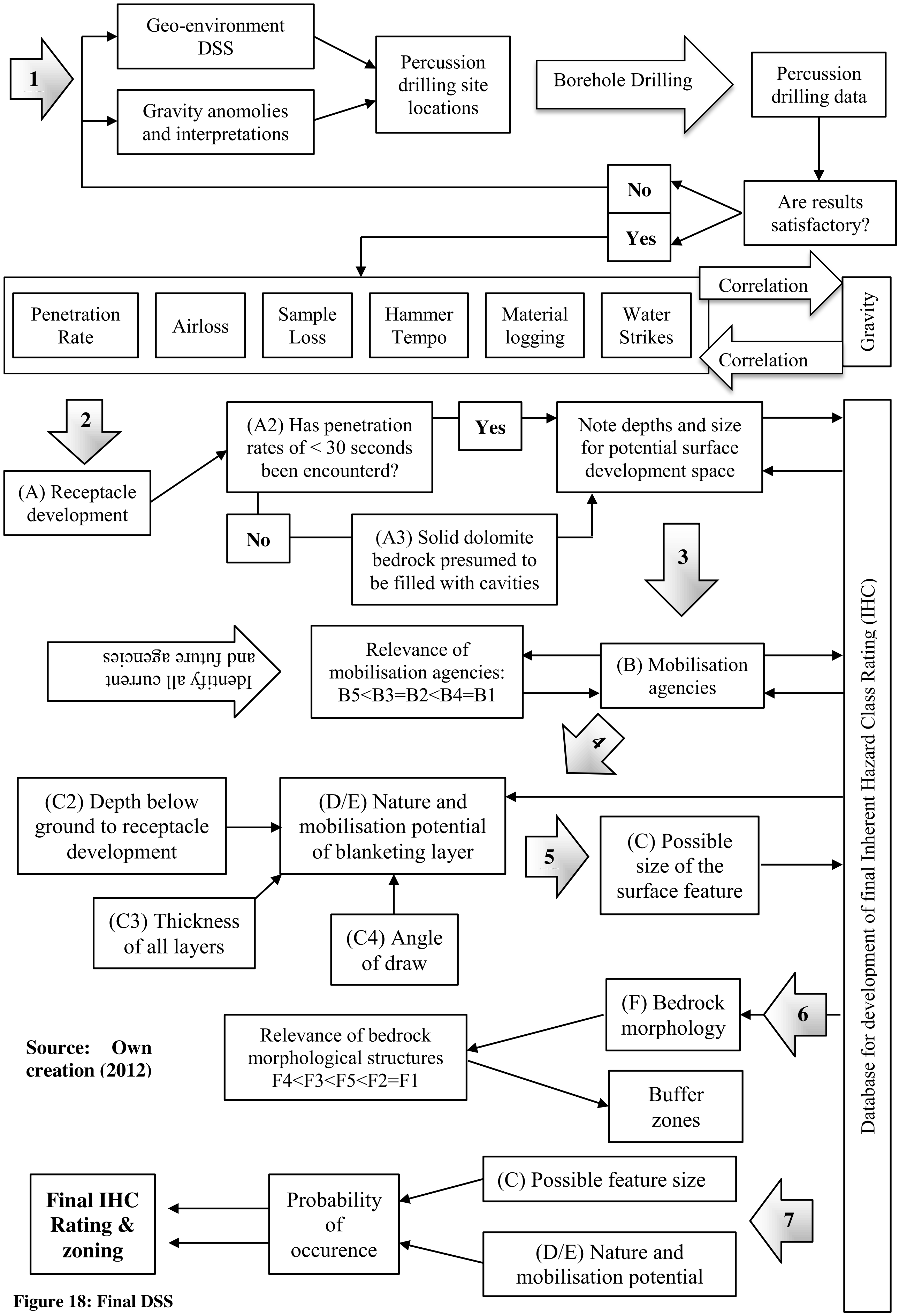
7 – Final evaluation

The geo-environmental site conditions are discussed first:



Source: Own creation (2012)

Figure 17: Geo-environmental DSS for risk contribution



Source: Own creation (2012)

Figure 18: Final DSS