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Protocol for

FREP Karst Evaluation at the Cutblock Level

Routine Effectiveness Evaluation

Version: October 30, 2020

Acknowledgements

As of 2020 Leah Malkinson is the Resource Value Team Lead for the Forest and Range Evaluation Program (FREP) and Christine Lohr is the designated karst value Lead. Tim Stokes has been the technical developer for this routine-level evaluation and protocol from 2015-2020, however, many others have contributed to this project since its inception by Peter Bradford in 2003. These people include Kerri Brownie, Steve Chatwin, John Crooks, Larry Duke, Jim Dunkley, Kevin Kiernan, Kevin Kilpatrick, Bill Marshal, Sean Muise, Mark Salzl, Paul Tataryn, Robert van der Zalm, and Andy Waines. Special thanks should be given to district staff members Scott Dunn, Christina Mardell and Sean Muise who participated in pilot testing, and for improving the 2009 version of the checklist and protocol. Christina Mardell should also be recognized for the collection of surface karst feature data during 2010-2012. The significant efforts of Paul Griffiths, Carol Ramsey and Bill I'Anson, are much appreciated for reviewing the 2018-2019 versions of the protocol and checklist, as are two external karst experts - Tom Aley (Ozark Undergound Lab) and Dan Doctor (USGS) in 2016. Many of the photographs and images used in this document have been provided by Paul Griffiths who developed the 2009 version of the protocol.

FRPA and FREP

The *Forest and Range Practices Act* (FRPA) was introduced in 2004 as part of the transition to a results-based forest practices framework in British Columbia. Under this approach to forest management, the forest industry is responsible for developing strategies to ensure the sustainable management of 11 resource values identified under FRPA. The BC government's role is to evaluate the effectiveness of these strategies in meeting objectives for the FRPA resource values, and to also ensure compliance with other practice requirements. FRPA's mandate is to maintain high environmental standards, and to promote innovation and cost-effective forest resource management.

The provincial Forest and Range Evaluation Program (FREP is led by the Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD). The *Forest and Range Practices Act* and Regulations provides the results-based forest and range management framework in British Columbia and includes professional reliance as a foundational principle. Under the results-based model, the government evaluates compliance with the law using the Compliance and Enforcement arm of FLNRORD. The effectiveness of forest and range practices for achieving management objectives, including sustainable resource management are covered by FREP. The results of FREP's effectiveness evaluations are peer reviewed and presented as multiple resource value assessments (MRVAs) and as extension reports for government officials, industry, the public and other stakeholders.

FREP is a long-term commitment by the BC government to:

- Assess the effectiveness of the *Forest and Range Practices Act* (FRPA) in achieving stewardship of the 11 resource values identified under FRPA;
- Identify issues regarding the implementation of forest policies, practices and legislation as they affect the resource values identified under FRPA; and
- Implement continuous improvement of forest management.

The above commitments are accomplished by:

- Evaluating the status or trends of resource and ecosystem values, and determining causal factors for disturbances;
- Determining whether resource values are being managed in a sustainable manner through proven or alternative forest practices; and
- Recommending options for changes to forest and range policies, practices and legislation, where required.

Additional information on FREP and the program structure can be found in the FREP web site at:

http://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/integrated-resource-monitoring/forest-range-evaluation-program

Foreword

The Karst Protocol was developed to provide supporting information and instructions for data collection using the Karst field checklist. This field checklist was designed so that routine evaluations can document the condition of a karst landscape following timber harvesting. The Karst field checklist is structured to facilitate systematic and repeatable disturbance data collection for six different categories of surface karst features (SKFs) and caves (CAs) within a sample area. The checklist also has a series of advanced options that allow for the evaluation of retention areas around SKFs, the broader karst landscape (BKL) and cave infiltration areas (CIAs). This checklist and the associated indicator questions have undergone preliminary field testing and will be further tested during pilot training with Stewardship staff in 2020 with the goal of incorporating improvements to this assessment method for 2021.

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1.0 Introduction

1.1 Goal of the FREP Karst Evaluation

The overall goal of the FREP Karst Evaluation is to determine whether current forest practices have met the objectives as outlined in the Karst Management Handbook for British Columbia[1] which are:

- maintain the capability of karst landscapes to regenerate healthy and productive forests after harvesting;
- maintain the high level of biodiversity associated with karst ecosystems, including surface and subsurface habitats;
- maintain the natural flows and water quality of karst hydrological systems;
- maintain the natural rates of air exchange between the surface and subsurface;
- manage and protect significant surface karst features (e.g., sinkholes, sinking streams, springs, and cave entrances) and subsurface karst resources (e.g., caves, underground streams, and subterranean fauna); and
- provide recreational opportunities where appropriate.

An additional goal of the FREP Karst Evaluation is to evaluate whether forest practices are protecting karst resource features as identified through Section 5(1)(a) of the *Government Actions Regulation* (GAR). This section of the GAR defines a "surface or subsurface element of a karst system" as a category of resource feature, which is one of the 11 FRPA Resource Values.

The FREP Priority Question for karst as a resource feature is as follows:

> *"Are current forest practices protecting and maintaining the structure, function and ecological integrity of the surface and subsurface elements of karst systems?"*

What is Karst?

Karst is a distinctive topography in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock (usually limestone, dolomite, or marble). This geological process, occurring over many thousands of years, results in unusual surface and subsurface features ranging from sinkholes, vertical shafts, disappearing streams, and springs, to complex underground drainage systems and caves.

Because impacts to karst are not readily observable (i.e., they can develop slowly over time such as gradual soil loss or take place below ground) they are difficult to determine. For the purposes of the FREP Karst Evaluation we assume that surface karst features such as sinkholes, sinking streams, karst springs, cave entrances, etc., are a proxy for the karst system. We further assume that if forestry-related disturbances

[1] https://www.for.gov.bc.ca/hfp/publications/00189/Karst-Mgmt-Handbook-web.pdf

to surface karst features are absent or very few, it is more likely that the structure, function and ecological integrity of the karst has been maintained.

The FREP Karst Evaluation focuses on recent disturbances related to forestry activities. Seven key disturbance indicators are used for the Karst field checklist:

- Loss of mature forest cover
- Post-harvest windthrow
- Introduced materials (e.g., logging slash or road construction materials)
- Disturbed forest floor, mineral soil and bedrock
- Burning
- Shade alteration
- Changes to understory vegetation

In addition to collecting data on the disturbance indicators the FREP Karst Evaluation also records information such as dimensions of surface karst features, details on disturbance, and karst terrain and site information. These additional data are important for later analysis of the procedure and add to the scientific understanding of how different karst features might be disturbed and impacted by forestry activities. Due to the complexity of karst systems and the lack of research on impacts of harvesting on British Columbia's karst, there is currently no impact rating resulting from this evaluation. Instead, the evaluator will review a summary of the collected data, and then answer a number of "Closing Questions". The Closing Questions will allow the evaluator to provide input of potential improvements to n forest practices within the karst sample area.

1.2 The Basic Framework of the FREP Karst Evaluation

The FREP Karst Evaluation requires the assessor to evaluate the effectiveness of forest practices in managing the karst in a Karst Sample Area (KSA) based on a series of specific indicator statements applied to karst features. The data is recorded on a digital checklist using an iPad.

A KSA will be defined by the assessor, and represents a continuous karst area in or adjacent to a cutblock that contains the surface karst features to be assessed in a day's field work.

Surface karst features (SKFs) are those features of the karst landscape that can be viewed by an observer on the ground up to the threshold of daylight in subsurface openings, including cave entrances. Typically, assessors will evaluate a sample of the total SKFs previously identified in the KFA or site plan. The potential exists, however; to evaluate every SKF in areas with a small number of features.

Once a KSA has been selected, there are six basic steps to conducting a karst effectiveness evaluation for the KSA:

1. Describe the KSAs within and/or linked to the cutblock or road;
2. Determine your sample design, with a target sample size = 10.
3. Collect basic information for each SKF sampled;
4. Collect the indicator data and providing indicator responses for each SKF sampled;
5. Review the summaries relating to disturbances ("Yes" responses) for each SKF assessed;

6. Compare results on SKF's within harvested areas versus those in retention areas;
7. Answer a series of closing questions and making final comments for the KSA.

2.0 Key Concepts and Definitions

2.1 Surface Karst Features and Caves

There are seven surface karst feature (SKF) types that can be evaluated using the FREP Karst Evaluation, and that might populate a KSA. These karst feature types are:

- Cave entrances (CE),
- Sinkholes (SH),
- Karst springs (KS),
- Sinking streams (SS) and sinking watercourses (SW),
- Epikarst exposures (EE) and,
- Other surface karst features (OT; e.g., karst canyons, cliffs, karst ponds, grikes, natural arches, karst hums, rock shelters, etc.)

Not all types of surface karst features will necessarily be represented in a KSA. For example, a KSA may not have exposed epikarst (EE) areas. As well, the distribution of karst features in a KSA can be highly variable.

Caves (CAs) are the only sub-surface karst features examined in the Basic Karst evaluation procedure. However, this evaluation is only based on an office review of information and does not require subsurface investigation. Cave infiltration areas (CIAs) that are the ground surface above caves can be examined as part of the Advanced Options of the Karst Management Effectiveness Evaluation.

2.1.1 Caves

A cave (CA) is defined as a natural cavity in the earth that connects with the surface, contains a zone of total darkness, and is large enough to admit a human. A cave includes any natural extensions, such as passages, chambers, crevices, pits, or any other subsurface openings, that contribute to the functioning of the cave system. Cave are classified by the KMH into two ways depending on their depth, dimensions and values, and should be examined and mapped during completion of a KFA to determine their extent and potential significance. Caves are not evaluated by underground investigation as part of the FREP Karst Evaluation. The Cave Evaluation section of the FREP Karst Evaluation (See Section 5.3.6) determines whether the caves in a KSA have been confirmed by a qualified person, if the caves have been mapped, and whether Cave Infiltration Areas (CIAs) has been delineated for the ground surface above the caves. If required, disturbances to CIAs and their associated retention areas can be assessed as part of the Advanced Options of the Karst Management Effectiveness E (See Section 7.8).

2.1.2 Cave Entrances

Cave entrances (CE) are surface openings large enough to admit a human being, connecting the interior cavities to a zone of complete darkness and a CA (see Figure 1).



Figure 1: Cave Entrance

A cave entrance is an integral part of a cave system and may be nested within one or more other surface karst features. For example, a cave entrance may be located within a sinkhole that receives a sinking stream. For evaluation purposes, the 'opening' of a cave entrance is typically defined by the threshold or mouth of the cave. For horizontal entrances, the dripline defines the edge of if the opening, and is a line on the ground formed at a cave entrance by drips of water from the rock above (see Figure 2). Methods for measuring the cross-sectional area of cave entrances are outlined in Appendix D of KISVAP. For a vertical cave entrance, there is no dripline and the opening is measured in plan view. When a cave entrance is enclosed within a karst depression (e.g., sinkhole), the 'cave entrance' is defined by the rim of the sinkhole as delineated by the upper slope break of the depression[2] for evaluation purposes (see Figure 3).



Figure 2: Cave Entrance Opening – The threshold or mouth of the cave entrance opening is indicated by the dashed line. The upper edge of this horizontal opening, which occurs within the grey limestone bedrock, defines what is known as the dripline.

[2] The upper slope break of the depression is where the inner slope of the sinkhole changes.



Figure 3: Threshold of a Cave Entrance in an Enclosing Depression – The threshold of a cave entrance within an enclosing depression occurs along the rim of the depression as approximately indicated by red dots.

2.1.3 Sinkholes

A sinkhole (SH) is a topographic depression with a closed rim, wider at the rim than at its base, and commonly has a circular or elliptical shape with a flat or funnel-shaped bottom (Figures 4 and 5). One or more sinkholes can be nested within larger enclosing depressions.



Figure 4: Example of a Small Sinkhole - This small sinkhole occurs in a second growth forested area. The sinkhole rim is indicated by the yellow dots. Note, epikarst zone in upper part of image.



Figure 5: Large Forested Sinkhole with Possible Microclimate

2.1.4 Karst Springs

A karst spring (KS) is subsurface flow that typically emerges at the surface from karst opening in bedrock (see Figure 6). These karst openings can in some cases be cave entrances. Karst springs can flow all year round or be seasonal. Their flow rates depend on recent rainfall conditions and the time of year. The channels below the karst spring, known as a 'rising streams', provide clues as to the nature and magnitude of these flows.



Figure 6: Karst Spring

2.1.5 Sinking Streams and Sinking Watercourses

A sinking stream (SS) has a definable alluvial channel that disappears underground at a distinct karst sink point, also called a swallet. The sink point is the location where the stream disappears subsurface at a distinct site which can be an opening and may sometimes be a cave entrance (see Figure 7). The average width of the sinking stream is determined by measuring the distance of bank-full cross sections at four locations spaced evenly along the sample segment.



Figure 7: Sinking Stream Entering a Sink Point

A sinking watercourse (SW) is a watercourse that sinks into the subsurface at a distinct sink point and possesses one or more of the following characteristics: poorly or non-defined channels (including flow over an organic bed); exhibits no evidence of scouring or alluvial deposition; or flows on the surface for less than 100 meters (see Figure 8). At a minimum, a sinking watercourse follows a confined, linear drainage course with a distinguishable cross-sectional low point, accompanied by the presence of hydrophytic vegetation (plants that thrive in saturated soils).



Figure 8: Sinking Watercourse in Harvested Area – Note, lack of well-defined alluvial channel and accumulations of small woody debris

2.1.6 Epikarst Exposures

Epikarst is the upper layer of karst and consists of a network of intersecting fissures and solution openings and cavities that collect and transport surface water and nutrients underground (see Figures 9 and 10). An epikarst exposure (EE) is a bare or uncovered portion of the epikarst, which can extend below the nearby soil/overburden cover. Epikarst exposures are often located on positive relief karst features (e.g., convex outcrops, hums, hummocks, hillocks and ridges). The depth of epikarst typically ranges from a few 10's cm up to a 1-2 m or in highly developed karst much more (5-10 m). If an epikarst exposure forms part of a larger distinguishable surface karst feature within the KSA (e.g., bedrock bluff), evaluate the larger surface karst feature only. Sub-sampling of large epikarst exposures maybe required where it is difficult to assess the nature and characteristics of disturbances over the entire epikarst exposure.



Figure 9: Epikarst Exposure in Cutblock



Figure 10: Close-up view of Epikarst with Vertical Solutional Openings

2.1.7 Other Surface Karst Features

There are a multitude of other (OT) surface karst features. These can include, but are not limited to: karst canyons, dry valleys, karst ponds, grikes, karst shafts, natural arches, karst hums, karst bluff, karst ridges, and rock shelters (see Figures 11 to 17). In some cases, surface karst features can be enclosed in large karst valleys or depressions (100 m to 1 km in dimensions). These might not always be obvious in the field but are more apparent on topographic maps or LiDAR. Sub-sampling of larger features might be one way to assess them as part of a FREP Karst Evaluation along with examination of mapping or imagery data. The classification key in Appendix 1 can be used to identify and classify many of the karst features in this category. Also refer to Appendix D in KISVAP for detailed descriptions.





Figure 11: Karst Canyon – Note, smooth and curved bedrock sidewalls in limestone.

Figure 12: Grike – Elongate solutional opening with length and depth much greater than width.





Figure 13: Karst Shaft – View up from base a karst shaft. Note sub-vertical sidewalls

Figure 14: Natural Arch





Figure 15: Karst Ridge – A high that extends as a linear feature.

Figure 16: Karst Hum – A high that occurs as a point feature



Figure 17: Karst Bluff – A karst bluff is a vertical or subvertical face of limestone that has a crest at the top and a toe along the bottom. In this case a small rock shelter occurs at the base.

2.2 Karst Feature Complexes

A Karst Feature Complex occurs where two or more surface karst features touch or overlap each other (see Figure 18). This can occur in numerous ways. For example, a cave entrance could be located at the

base of a sinkhole (CE in SH), alternatively a sinking stream can lead into a sinkhole, which then flows into an opening that is a cave entrance (SS into SH with CE). These can be considered as nested or compound karst features - whereby one karst feature is located inside a larger enclosing karst feature. Feature complexes are likely sensitive on the karst landscape due to openings that link the surface to the subsurface. in terms of karst management, compound features might warrant some protection, with the use of karst reserves, retention areas or special management sites.



Figure 18: Example of a Karst Feature Complex – Note the three sinking streams in cutblock flowing from foreground and right side of image into the enclosing sinkhole (yellow dashed line) where two sink points are present. Possible karst spring or window on left side of image.

What is a Karst Feature Complex?

A karst feature complex is a combination of two or more surface karst features that are touching or overlapping each other.

2.3 Karst Feature Clusters

Typically, many surface karst features occur in clusters when two or more surface karst features are separated on the by a distance no greater than twice the greatest dimension of the closest neighbour. The component features do not touch or overlap each other but are physically apart on the surface. In

many cases, sinkholes occur in clusters, and in some cases, can form 'sinkhole-fields'. The presence of karst feature clusters is important from both a karst system and karst management perspective. In terms of the karst system, karst feature clusters, like karst feature complexes, possibly suggest a more sensitive part of the karst landscape with closer linkages between the surface and subsurface. In terms of karst management, feature clusters might potentially warrant more protection, particularly with the use of karst reserves or retention areas.

It is possible that a cluster consists of non-notable features such as sinkholes less than 5m in diameter. (See Section 2.5 following for definition of "notable features".)

What is a Karst Feature Cluster?

A karst feature cluster is defined as two or more distinct surface karst features that are physically separated on the surface by a distance no greater than twice the greatest dimension of the closest other neighbour. The component features do not touch or overlap each other.



Figure 19: Example of a Karst Feature Cluster - Note, the three sinkholes in a line and within twice times their diameter in terms of distance. Rims of sinkholes marked by yellow dots. Possible dry draws noted upslope and to right of image.

2.4 2-Metre Measurement Zone

For the purposes of the FREP Karst Evaluation, a 2-m zone or envelope has been added to the outside of features to account for potential errors in measurement and for the rooting of any large trees located

on the edge of features. This 2 m zone does not imply anything with respect to the protection of the feature.

For sinkholes 2 m should be measured outward from the rim and any disturbances found within this 2 m zone included in the evaluation. For karst springs the 2 m should be measured outward from the edge of the opening or rim of enclosing depression, likewise for cave entrances the measurement should be from the dripline or rim of the enclosing depression. For SS the measurement should be 2 m outward either side from the channel banks, while for SW it should be from the center of the watercourse. Measurement for EEs and OTs can be more flexible, but the 2 m rule should be followed where possible.



Figure 20: 2 m Zone measured from the rim of a Sinkhole.

2.5 Notable Features

All the SKFs that are sampled should be notable features[3] on the karst surface. Dimension is not always the best guide in deciding as to whether features are notable or not. For example, many karst spring openings and cave entrances are small, but their function is important providing open connections to the subsurface and/or possible ecological values.

[3] As per the KISVAP, page 56, notable features are defined as "… those that are easily recognized, and where the potential for feature-specific management is anticipated. Minor features that do not fall into this category are not individually assessed."

3.0 FREP Karst Evaluation – Office Preparation

3.1 Office Preparation and Planning

An office review of existing information on a cutblock prior to field work is essential for completing a successful FREP Karst Evaluation. Copies of the following information and any other applicable records or maps should be assembled for each cutblock to be sampled:

- Operational plans (i.e., site plans);
- Karst inventory reports, geotechnical reports and/or karst field assessments;
- Karst potential and bedrock mapping from the Data Warehouse (iMapBC, MapView, ARcMap);
- Higher resolution satellite images (e.g., from Google Earth); and
- LiDAR (if available).

Stereoscopic pairs of post-harvest air photos and/or Google Earth imagery can sometimes be used to confirm the presence of karst in recently harvested areas and identify the likely locations of surface karst features as well as variations in topography and access. Access and efficient walking routes for most KSAs can also be developed using imagery and cutblock plans.

3.2 Cutblock Selection

The population to be used for a FREP Karst Evaluation includes all cutblocks harvested within 1-3 years ago, and that occur on karst terrain. All sites sampled will be randomly selected.

The number of sites or cut-blocks sampled can vary depending on available resources, but should target n=30 over a 5 year period per district.

A random list of cutblocks overtop of karst potential terrain will be prepared annually by Resource Planning and Assessment Branch.[4]

From this list, cutblocks will be selected as potential KSA sample sites. Contact the license holder and request the site plan, karst inventory, and/or Karst Field Assessment (KFA) for each block. The following additional steps are applied to the random list to determine whether the block should be dropped or not:

a. Block has no karst: If it was determined that there is no karst present within the cut-block, and also that the cut-block boundary was not adjusted to avoid a nearby karst feature, then this block is not to be included in the KSA list.

b. Harvest area avoids karst: If it was determined that there is karst present, but the cut-block boundary was adjusted or set back 100m or less to avoid the karst, then this block should be added to the KSA list. Similarly, if a retention area was placed on karst

[4] The selection criteria are the following: 1) The listed cut-blocks will be those that are 1-3 years since harvest completion date. The minimum 1-year period is needed to ensure that all sites were exposed to at least one season of post-harvest environmental conditions (e.g., wind storms, burning of slash piles); and 2) The cut-block intersects a karst potential polygon labeled 'high' or 'moderate' karst development intensity in combination with primary karst likelihood.

feature(s), but there are no features in the harvest area, then this block should be kept in the KSA list.

c. Karst is present in harvest area: If the site plan, karst inventory data, and/or KFA determined karst was present, then the block should be kept in the KSA list.

d. Karst is present at access roads – where the block is outside the karst unit but the road crosses the karst unit, the associated block should be kept in the KSA list. The KSA selected includes either side of the access road for approximately 100 m.

e. KSAs may be added or removed from the KSA list for specific reasons, which should be recorded. For example, a KSA may be deleted from the population for safety concerns or could be added if targeting KSAs with a high density of features. If there are other reasons for adding or deleting a KSA, all these should be referred to the Karst Resource Value Lead.

3.3 Identify the Karst Sample Areas (KSAs)

The KSA is a continuous or uninterrupted karst area that is linked to a cutblock, is typically greater than 1 ha in size and contains karst features and/or karst terrain capable of being sampled in one day. KSAs may be smaller where the number of features is small and/or concentrated in an area less than 1 ha in size.

Location of KSA: The approximate limits of the KSA to be evaluated need to be delineated on a cutblock map prior to field work.

- This can be relatively straightforward where a KFA or site plan has identified the karst resources and depicts the extent of the karst unit. If the boundaries of the karst unit are known, it is usually much easier not only to define the extent of the KSA, but also to better understand the nature and distribution of SKFs in an area.
- A KSA can extend outside of a cutblock into adjacent forest areas by up to 100 m if they contain SKFs intentionally excluded from the harvest area.
- A KSA can extend outside and along access roads by up to 100 m if they contain SKFs that were intentionally excluded from the harvest area.
- Overall, the KSA should be as representative of the karst resources at the site as possible and include a range of surface karst features, topographic conditions and karst landscapes.
- The KSA should mainly include harvested areas with roads and any retention areas within or adjacent to the cutblock.

Examples of typical KSA configurations are outlined in Figure 21.

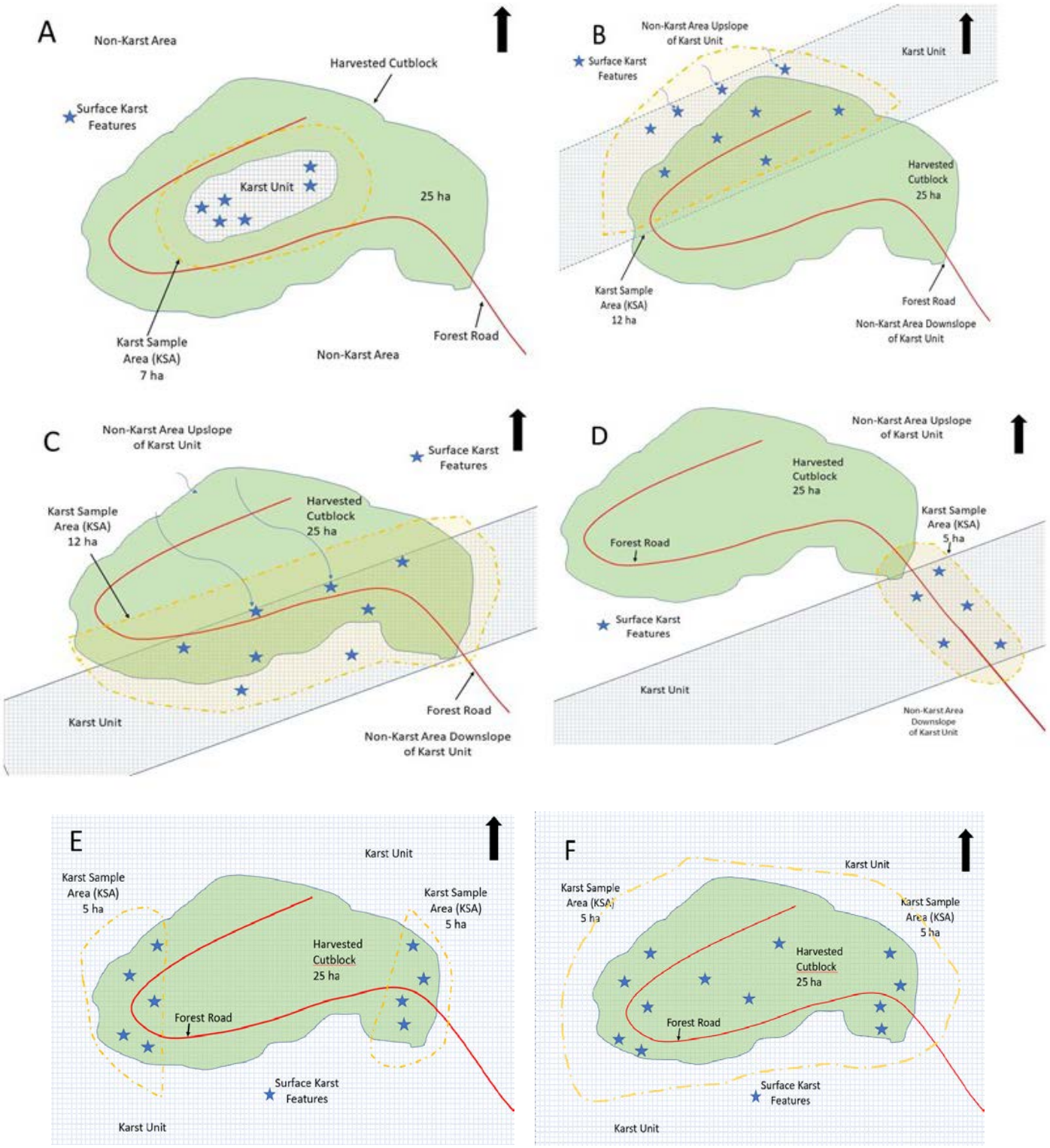


Figure 21: Examples of different Karst Samples Area (KSA) compared to Karst Unit Configurations

Example A – Small karst unit occurring with the centre of a cutblock. The KSA boundaries surrounds the karst unit and extends some distance beyond.

Example B – The karst unit is in upper part of cutblock and includes several surface karst features/sink streams outside of cutblock. In this case the KSA includes these features as well as others in cutblock.

Example C – The karst unit is in the lower part of the cutblock with several sinking streams extending into non karst areas of the cutblock. The KSA boundaries includes these sinking streams and their sink points, plus other surface karst features within the cutblock and below the lower boundary.

Example D – The karst unit is outside the cutblock but crosses the access road. The KSA selected includes either side of the access road for approximately 100 m.

Example E – The cutblock in this case is in the centre of a large karst unit. Rather than having the KSA include all the cutblock two smaller KSA areas have been chosen, each which concentrate the sample area to where features are located.

Example F – A smaller block with the KSA covering the entire cutblock area.

3.4 Sample Design

3.4.1 Goals and Principles of Sampling the KSA

Ideally, the evaluation will objectively assess a diversity of important karst features in the harvest and retention areas of a cutblock or access road. For the purposes of this Protocol, retention areas may consist of any area excluded from harvest such as: karst reserves, karst management areas, wildlife tree patches or wildlife tree retention areas (WTRAs), riparian reserves, riparian management areas, and even non-harvest area outside of, but within 100m of the harvest area.

As a routine effectiveness evaluation, the goal is to evaluate one Karst Sample Area (KSA) in a field day. It is recommended that a sampling plan be developed with a targeted size of 10 features (n=10). If there is not time to evaluate all 10 because of access, terrain or other considerations, a minimum of 4-10 features in one field day is considered acceptable.

In the field, always evaluate priority features first in case of time imitations. Where the number of features within a KSA is greater than 10, a sampling plan needs to be developed that is statistically sound. This plan will be based on the “known surface karst features” – those that were previously identified in informational documents such as the site plan, site plan map, karst inventory data, or karst field assessment (KFA). Features will be selected from the known features in a systematic manner to reduce bias. Certain circumstances may arise in the field that may warrant adjusting the sampling plan: these adjustments also need to be made in a structured manner (see Section 5.3.4).

3.4.2 Building a Stratified Random Sample for the KSA

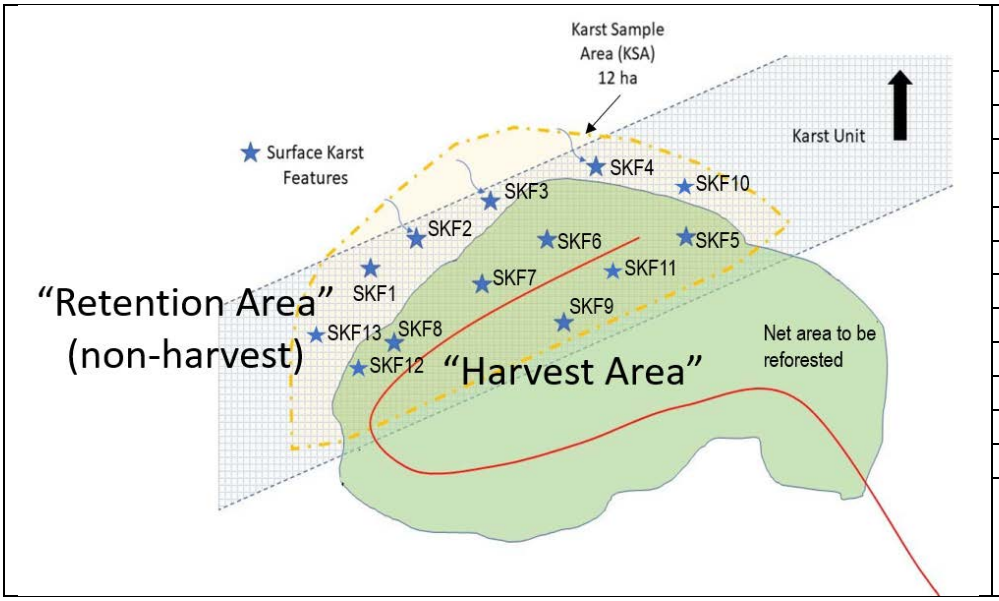
Step 1: In general, only notable features should be evaluated.

All the SKFs that are evaluated should be notable features. An exception to this, however, is when a group containing non-notable features form a cluster. In that case, the cluster is to be considered in developing your sampling plan.

Step 2: Group the features by category.

Review the site plan, KFA, karst inventory data, and/or site plan map to identify the known surface karst features for a KSA. Features within 100m of the cutblock or access block are to be included in this pool, as are features within WTRAs or other in-block reserves.

Figure 22 below is a hypothetical set of features located in a karst sample area. This example shows that some features are located outside the block, but are within 100m of the boundary and are therefore considered to be part of the KSA.



Feature #	Feature Type
SKF1	SH
SKF2	CE
SKF3	SH
SKF4	SH
SKF5	SH
SKF6	EE
SKF7	EE
SKF8	KS
SKF9	OT
SKF10	SH
SKF11	SH
SKF12	CE
SKF13	SH

Figure 22. Example of surface karst features (SKFs) in a hypothetical Karst Sample Area (KSA).

The karst features that represent greater connectivity between the surface and subsurface are likely the most sensitive to disturbance. This may include features in complexes and clusters, as well as cave entrances, karst springs and sinking streams.

In this step, organize the known features within your KSA by feature type, using the categories described in Table 1.

Identifying the feature type for the purposes of this Protocol may require some interpretation of the information provided by the forest licensee. For example, a karst spring may be described as an "exurgence". You may also see mapped locations where a group of nested features occur (e.g. a cave entrance within a sinkhole). Such nested features are to be classified as *feature complexes* for the

purposes of this Protocol, but otherwise the term *feature complex* is probably not used in licensee documents.

Table 1. Feature types, in order of priority for sampling. As an example, the table has been populated with hypothetical features from a hypothetic KSA.

Known Feature Type – in sampling order						
Cave Entrance (CE)	**Karst Spring (KS)**	**Sinking Stream (SS)**	**Sinkholes (SH)**	**Other (OT)**	**Epikarst Exposures (EE)**	**Sinking Watercourses (SW)**
SKF2 SKF12	SKF8		SKF1 SKF3 SKF4 SKF5 SKF10 SKF11 SKF13	SKF9	SKF6 SKF7	

Step 3: Select features to include into the sampling plan.

If the number of known surface karst features within a KSA is 10 or less, then plan on evaluating them all. If you have a feature complex, you may be able to sample all of the components if your number of known features is small, and time permits in the field.

Otherwise if the number of known surface karst features is greater than 10, draw your sample as follows:

A. Randomly select one feature from each of the 7 categories. (Refer to Appendix 2 for random selection techniques).

B. Next, randomly select one additional feature from each category, starting with the left-most category (Cave Entrances) and progressing through each subsequent category from left to right. Stop at any point if you reach n= 10.

C. Iterate step B until you reach n=10

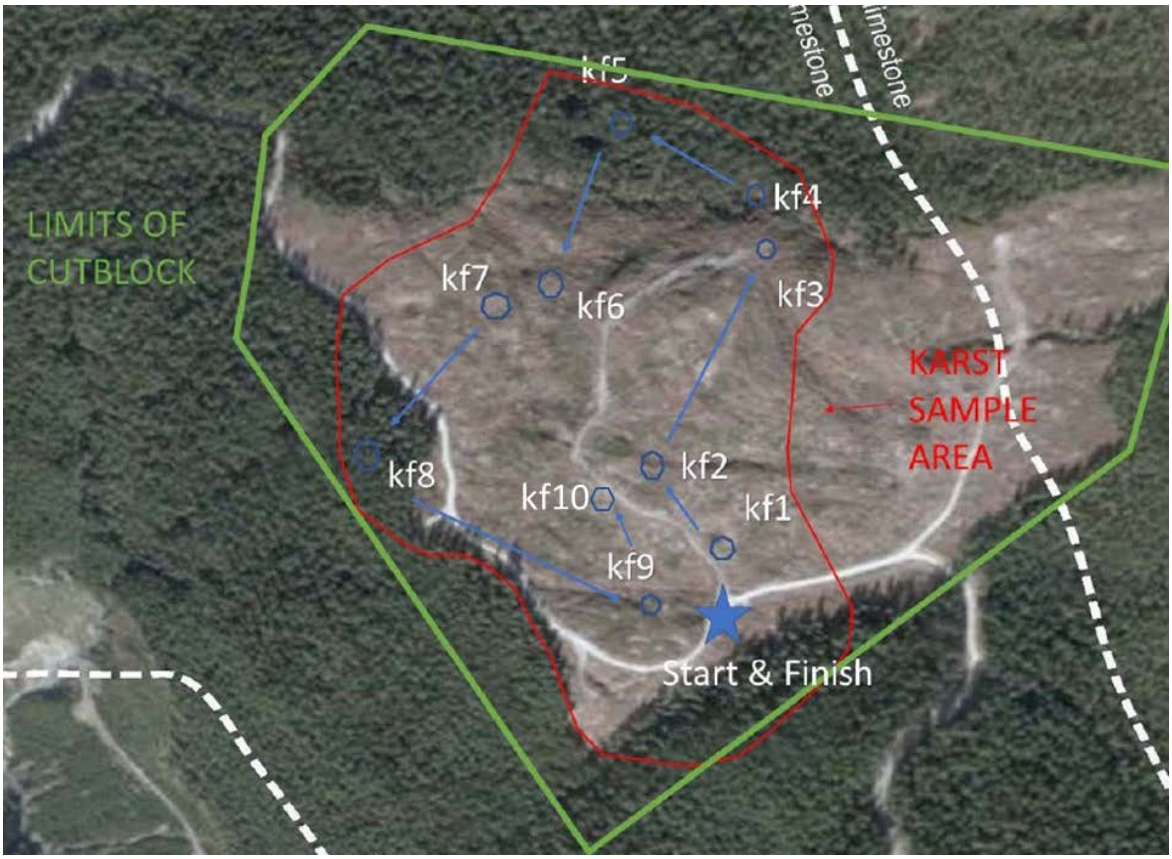


Figure 23: Sampling Plan for Evaluating Selected SKFs in a Hypothetical KSA

3.4.3 When Feature Type is Unknown

There may be situations when the site plan or other pre-harvest assessment notes the location of a SKF **but not the type**. If this happens, randomly select a maximum of n=10 for sampling. Ensure that this alternative sampling methodology is documented in the KSA "Comments & Documents" tab on the Karst Field Checklist.

3.4.4 Advanced Options for FREP Karst Evaluations

There may also be a need to consider the Advanced Options for examining Retention Areas, Broader Karst Landscape and whether a Cave Infiltration Area (CIA) needs to be assessed. Refer to Section 6.0 for details on these advanced components.

4.0 Karst Field Checklist

The karst field checklist is a digital file (.fmp12) to be used on an iPad. The checklist was developed with FilemakerPro software and is opened using the Claris FilemakerGo app, Version 18 or 19. The iPad must be version iOS 13.2 or newer. This digital format is the primary way in which FREP Karst Evaluation data is collected in the field. However, as part of the office preparation, it is strongly recommended that

certain background and descriptive information about the KSA be entered onto the checklist in advance of leaving for the field.

Information collected on the karst field checklist can be downloaded or e-mailed for backup and data storage following completion of the field work. Appendix 3 outlines how to use FilemakerGo including: loading and downloading files, printing information, moving between screens, and trouble shooting.

The Karst field checklist on FilemakerGo is divided into four main sections (tabs): ***Office, Field, Closing*** and ***Summary***. Each of those are further comprised of one or more sections.

4.1. Office

The ***Office*** section is further subdivided into two tabs: ***Start Here*** and ***KSA***.

- General Information for the Karst Effectiveness Evaluation: The ***Office/Start Here*** tab is used to enter general information of the cutblock.
- Karst Sample Area (KSA): There are 6 tabs under ***Office/KSA*** used to identify KSA and enter information such as its size and location, length of roads, relationship to karst unit, details on KFAs or karst inventories, KSA terrain characteristics, prior disturbance activities, and number of surface karst features.

4.2. Field

The ***Field*** section is further divided into 3 tabs: ***Surface Karst Features***, ***Broader Karst Landscape*** and ***Cave.***

- Surface Karst Features (SKFs): The **Field/Surface Karst Features** section is further divided into 5 sections: ***SKF Info, Disturbance Indicators, Retention Areas, Disturbance Indicators to Retention Areas*** and ***Photos & Comments***.
    - The ***SKF Info*** tabs are used for entering of general information or comments pertaining to the surface karst feature sampled, as well as for entering details pertaining to the specific type of surface karst feature.
    - The ***Disturbance Indicators*** tabs are used to collect information on the different disturbance types at a SKF. A Yes/No response will be entered as to whether a disturbance is present or not.
    - Retention Area Surrounding SKFs (Advanced Option) – There are 3 tabs under ***Field/Surface Karst Features/Retention Areas*** used to collect information on the types and size of the retention area that surround SKF. There are also 6 tabs under ***Field/Surface Karst Features/Disturbance Indicators to Retention Areas*** used to answer Yes/No to four disturbance indicators and enter specific details.

- Broader Karst Landscape (BKL; Advanced Option) – There are 3 tabs under ***Field/Broader Karst Landscape/BKL Info*** used to enter information on BKL sample plots located within the harvest area or in forested areas. There are also 7 tabs under ***Field/Broader Karst Landscape/Disturbance Indicators*** to answer Yes/No to the disturbance indicator questions, and enter in specific details.

- Cave Evaluation – The tab, ***Field/Cave,*** used to collect information on any known cave and determine whether it has been confirmed by a qualified person, has been mapped and if a CIA has been determined.
    - Cave Infiltration Areas (Advanced Option) – There are 6 tabs under ***Field/Cave/CIAs and Retention*** used to enter information collected on cave infiltration areas (CIAs), as well their retention areas and associated disturbances.

4.3. Summary

A series of summary tables are also included under the main ***Summary*** tab. These are a useful way to compile and analyze the data collected in preparation for the closing questions.

4.4. Closing

There are 5 tabs under the main ***Closing*** tab where one answers summary questions on karst inventory information for the KSA, forestry practices, recent disturbances, past disturbances, and karst management practices and effectiveness.

5.0 FREP Karst Evaluation – Field Methodology

5.1. Getting Started for Field Work

5.1.1 Required Materials and Field Gear

The following is a list of the materials and field gear required to conduct a Karst Effectiveness Evaluation:

- An iPad iOs 13.2 or newer, with the following loaded onto it: Claris Filemaker Go18 or 19, the karst field checklist, the karst reference documents file, and PDF Map Apps (e.g. Avenza)[5],
- An annotated field map with the limits of KSA, SKFs to assess based on sample plan, the approximate karst unit boundaries and the proposed walking route,
- A calculator,
- A soil rod for measuring soil depth (optional),
- Field gear (e.g., rain wear, hard hat or helmet with chinstrap, cruising vest, pencils, a field notebook, safety/first aid supplies, flashlight or head lamp),
- Suitable footwear for walking on karst landscapes[6],
- Compass, clinometer and a measuring device (e.g., laser distance meter, hip chain, hand-held tape),
- Flags, or flagging tape and marking pens (to mark features or sample plots as needed)

[5] Only I-Pads and I-Pad minis with cellular capability have a GPS chip that can work out of Wi-Fi and cellular range. Note that I-Pad includes a camera which is connected directly to checklist.

[6] Karst field work can involve walking on hazardous micro-topography with uneven and wet bedrock surfaces. Waterproof boots are recommended. Caulked boots should be avoided if possible due to the slipping hazard on smooth bedrock surfaces and their potential to damage sensitive karst features.

5.1.2 What is the Best Time of Year to Conduct Karst Effectiveness Evaluations?

Karst effectiveness evaluations can be done in the field at any time of the year the ground is clearly visible (i.e., no snow). Conducting evaluations when the foliage is not fully developed or after leaf fall may assist in making small karst features easier to see. For most areas of BC, the optimum conditions for Karst evaluations is from spring to early fall, although this timeframe may be extended at lower elevation sites along the coast.

The optimal time for assessing sinking streams is during low flow periods when the streambed, stream banks, and ground in the riparian area are clearly visible. In addition, fine debris deposited during high flows may only be visible on the streambed during low flow periods. During high flow stage conditions, the normal stream channel may not be clearly visible. However, karst springs are more readily noticed during high flow periods, particularly if they are intermittent.

Several indicators, such as the condition of understory vegetation, are best observed during the growing season. Shade levels can be difficult to assess after the leaf fall in areas where the forest cover is in part deciduous.

In most cases the FREP Karst Evaluation is best done as a 'team of two' in the field – a team leader and an assistant. One person should be focused on recording the information using the digital field checklist and the I-Pad, while the second person should be locating features, measuring distances and assisting with observations. With practice, an efficient team should be able to relatively quickly evaluate a reasonable number of SKF sample site during a day's field work. For example, it may be possible to evaluate 2-3 SKFs per hour.

5.2 Confirm the Karst Sample Areas (KSAs) and Sampling Sequence

The types and amount of background karst information available for a site is particularly important, as it can constrain factors such as: the limits of the KSA, the known boundaries of the karst unit, knowledge of surface karst features or caves present. However, when you arrive at a particular evaluation area (cutblock or road), it is recommended that you conduct a reconnaissance of the KSA before SKF sampling, as this can tell you a lot about the type of disturbance at the site (e.g., roads).

Other site conditions such as access (i.e., drivable verses non-drivable roads), steep and/or irregular terrain, windthrow areas, etc. play a role in how a FREP Karst Evaluation is completed. Review the planned sequence for your sampling plan and make adjustments if appropriate. For example, if the KSA is a long walk from the truck, then you may need to adjust the sampling sequence and to find the most efficient walking route.

5.2.1 Strategies When Faced with the Unexpected

If undocumented surface karst features are encountered during the FREP Karst Evaluation, their location and type will be documented and measurements taken, but they will not be evaluated for disturbance. Site selection is completed beforehand through random selection, and features are selected through a systematic process. Including additional undocumented features could create a bias. At this time, this sampling methodology will be trialed using the prior known features as a basis for sampling, and as means of maintaining unbiased selection of features.

If you cannot find a feature

It is possible that you may not be able to find a feature in your sampling plan. In this case, select the next closest feature if one is available.

If your feature turns out to be "non-notable"

If a feature in your sampling plan unexpectedly turns out to be non-notable, e.g. you find that one of the sinkholes in your sampling plan is only 3 m in diameter and 0.5 m deep. Technically this sinkhole is non-notable due to its small size. Proceed with the evaluation anyway but please insert a comment that the feature is non-notable.

If your feature is misidentified

It is quite possible that features have been incorrectly identified in the site plan or other assessment documents. In this case, proceed with the evaluation of this feature, but ensure it is correctly categorized in the karst field checklist.

If you don't have enough time to evaluate all the features

It is possible that you will run out of time and not be able to evaluate all of the features in the Sampling Plan. If feasible, plan your field day so that you evaluate features in a sequence whereby higher sensitivity features are evaluated first.

5.3 Complete the Karst Field Checklist

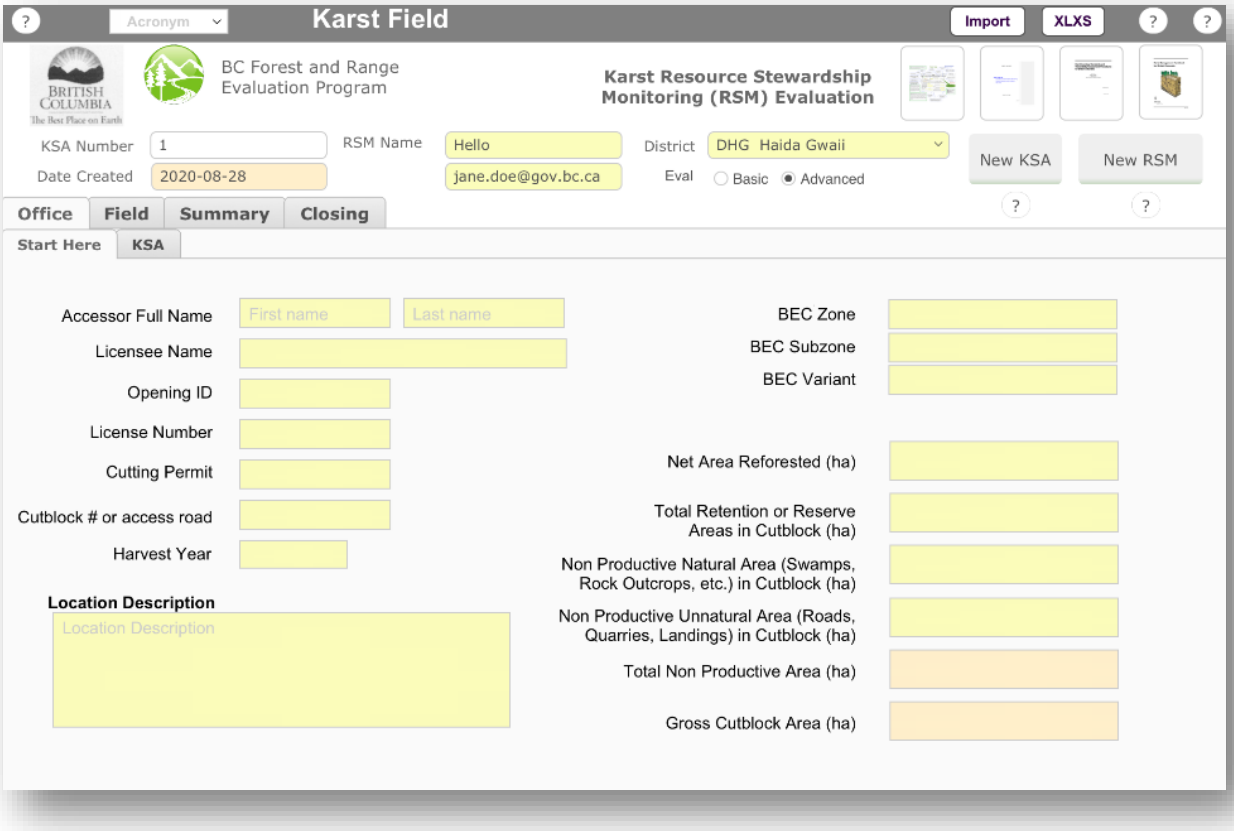
The sections below outline the basic framework of the digital field checklist, and provide details on how to collect the data for the various tabs. Each section of the checklist is organized by the tabs under the 4 main parts (***Office, Field, Closing*** and ***Summary***) to allow for easy referencing between the Filemaker App and this document.

5.3.1 *Office/ Start Here* – General Information

The ***Office/Start Here*** tabs are used to enter descriptive information needed to identify the FREP Karst Evaluation site. When the digital checklist is first opened using the Filemaker app, a new RSM Evaluation with a new KSA and new SKF is in place and ready to go. These have default naming or numbering which should be changed. If you do click on New KSA at this point, then you will have two KSAs started.

To start an additional RSM Evaluation, under the main ***Office*** tab, click ***Start Here***, and click on New RSM for any additional cutblock you will be sampling. Some of this general information can be entered in advance as part of the office preparation.

The Evaluation Type defaults to "Basic" which includes the Basic Level of evaluation (KSA, SKF - Info, SKF - Disturbance Indicators & Cave Evaluation). Click on "Advanced" if the Advanced Options are required (SKF - Retention Areas and Disturbance Indicators, BKL - Info, BKL - Disturbance Indicators, CIA & Retention Areas). In most cases just the Basic Level is used.



5.3.2 *Office/KSA* - Karst Sample Area (KSA)

Under the ***Office*** tab, click on the ***KSA*** tab. A new KSA is automatically created and will default to KSA Number 1. If there are multiple KSAs under a given RSM evaluation, you may click on New KSA. Otherwise a new KSA defaults and you do not need to click on New KSA.

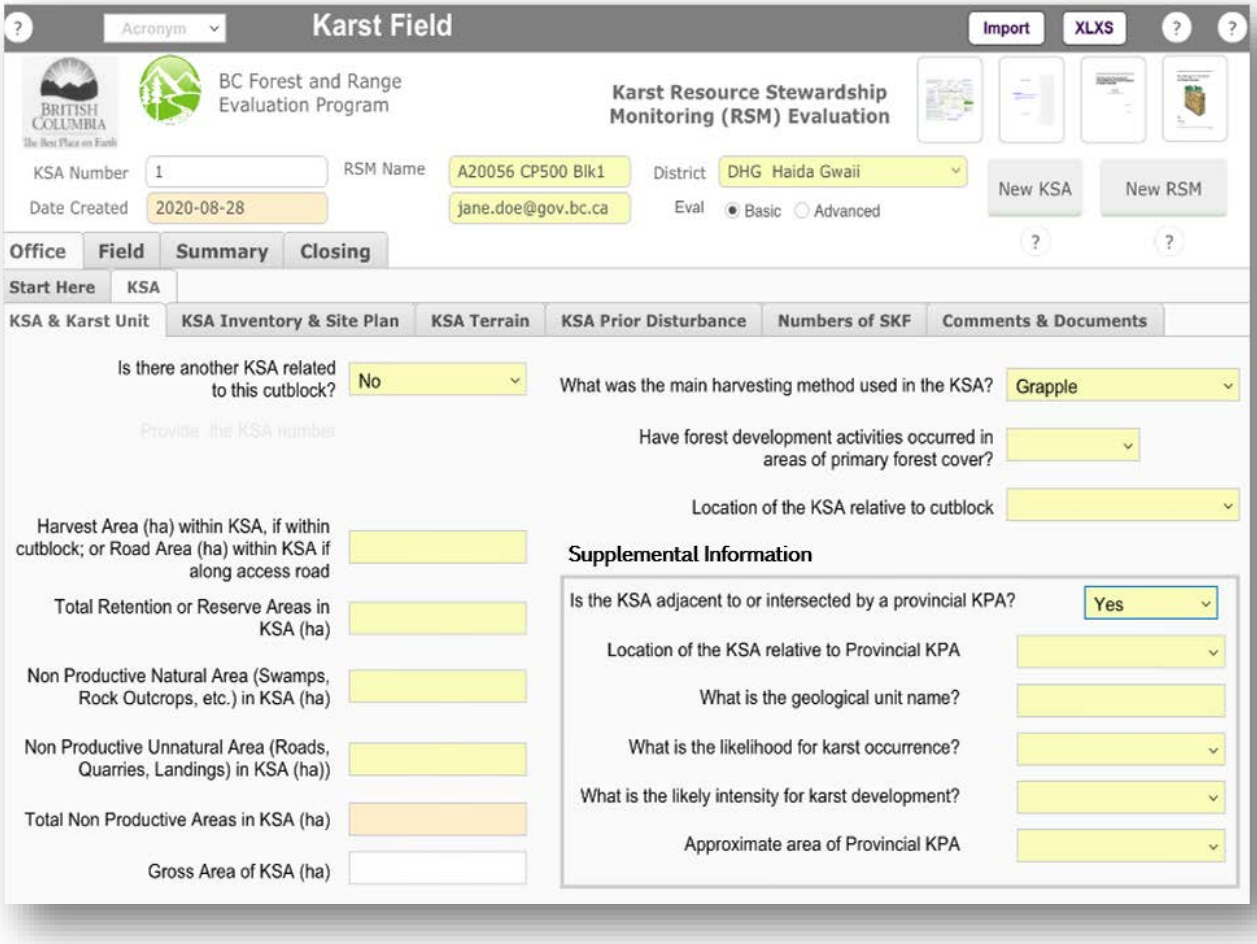
Under the ***Office/KSA*** tab, there are 6 tabs for entering information about the karst sample area (KSA) you will be sampling. These 6 tabs collect information such as the size of the KSA, location relative to the cutblock and karst unit, details on KFAs or karst inventories for the KSA, the KSA terrain characteristics, prior disturbances in the KSA, and the number of known, previously unknown and sampled surface karst features. Most of these pages can be filled as part of the office review and the field planning component of the FREP Karst Evaluation.

KSA & Karst Unit

The ***KSA & Karst Unit*** tab includes basic details on the KSA and the karst unit within which the KSA is located. These questions are intended to gather information on the forest activities on the KSA and determine the location of the KSA relative to the cutblock and to the host karst unit.

Information relating to size of the KSA area (ha); the harvest area (ha) within the KSA; the road length (m) etc., can be determined from the site plan and map.

The total area of permanent access structures in KSA (ha) is important as directly related to disturbances on karst landscapes: the higher this number the greater the disturbance to the karst surface in the KSA, particularly if the karst has as High or Very High Surface Karst Sensitivity (SKS).



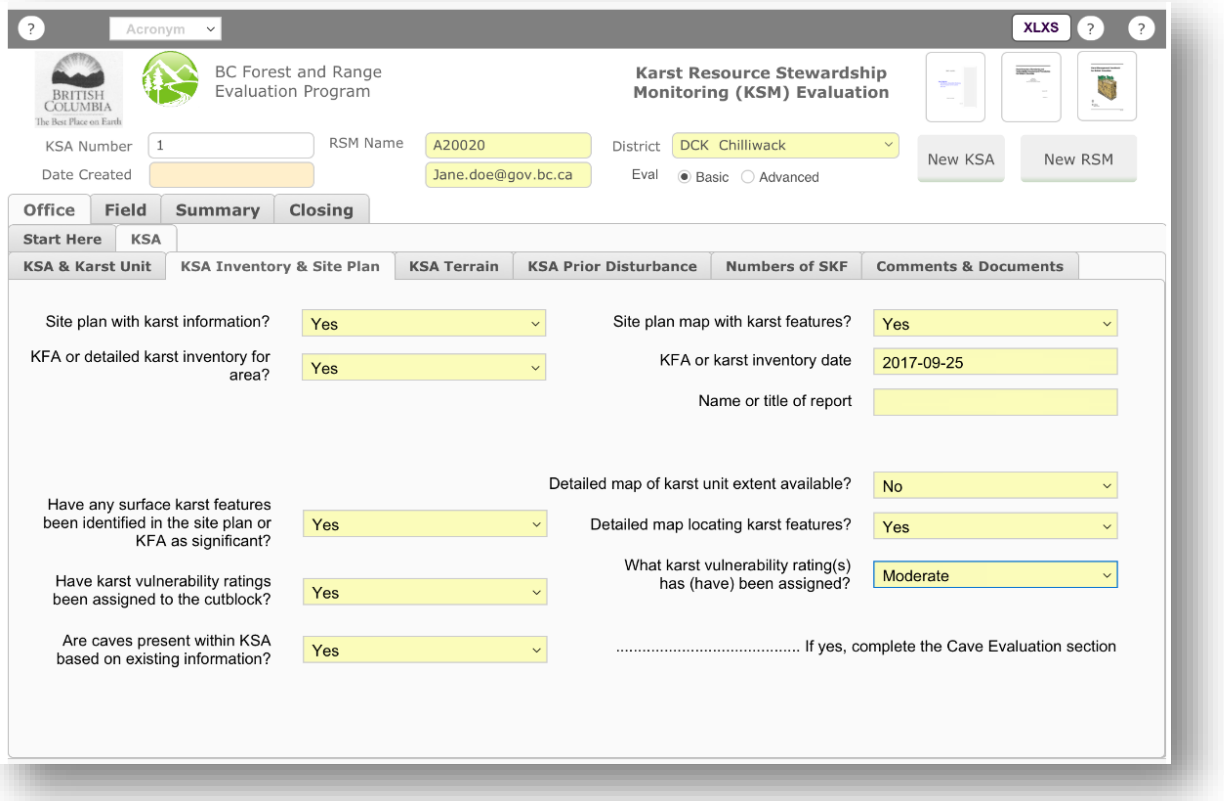
Information relating to harvest method is important (e.g. ground-based versus cable yarding), due to potential to significant effect/impact to a KSA and depends in part on the sensitivity of the karst landscape (e.g., the greater the SKS or roughness rating of the KSA, the greater the likely impact). Ground-based methods likely have more impact than cable yarding methods with lift.

Whether forest development activities have occurred in areas of primary forest cover is also important for later analysis of KSAs examining cumulative effects.

It is recommended that information relating to the geology of the karst unit be included – answers can be obtained using a GIS mapping environment and overlays of the KSA, cutblock, and karst mapping data. Karst mapping data can be gathered from regional bedrock geology maps, KFAs, karst planning maps, or the reconnaissance 1;250,000 scale karst potential polygons which are part of BC's Data Warehouse. This could be done before going into the field to help identify boundaries of karst unit.

KSA Inventory & Site Plan

This tab examines what karst inventory, KFA, and other information is available for the KSA. It also determines if known caves are present. If a 'Yes' responses are provided, additional information is required.



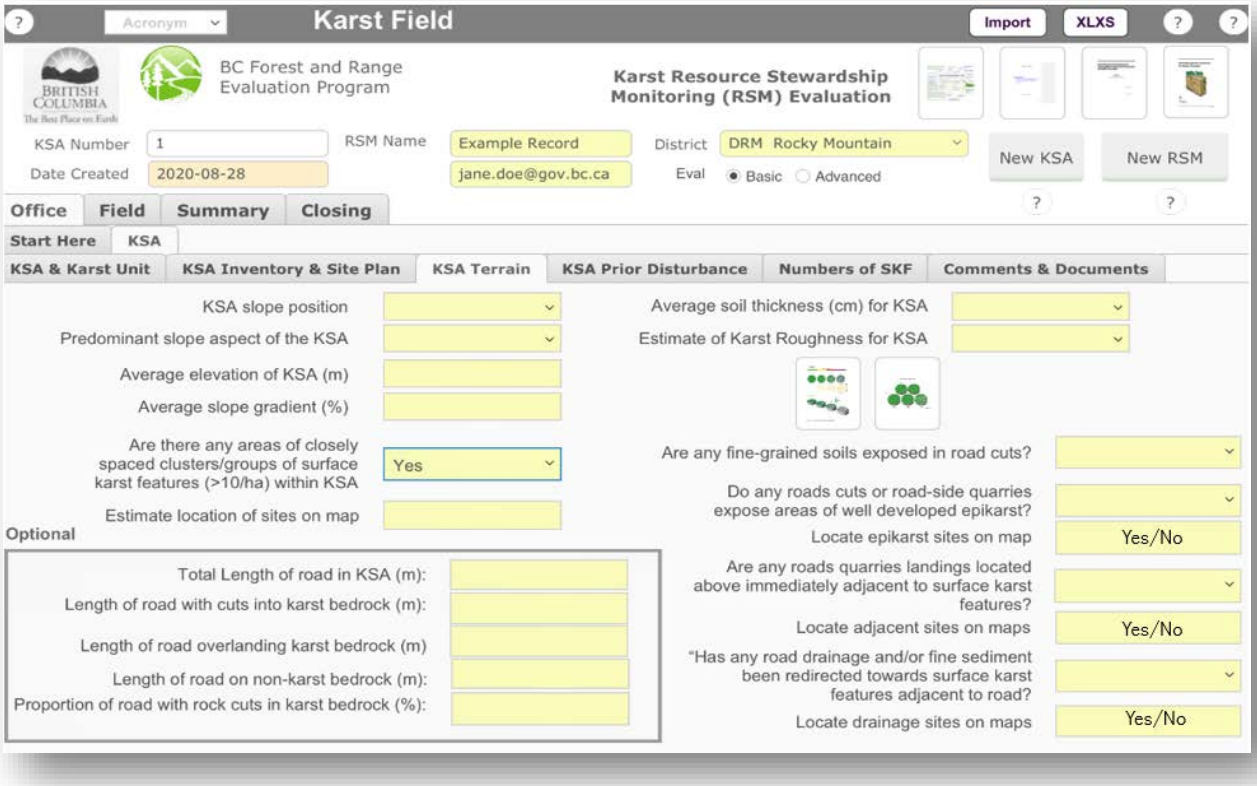
KSA Terrain Characteristics

The ***KSA Terrain*** tab collects terrain, topographic and other information on the KSA. Most of this information can be collected from the cutblock map, LDRW data, topographic mapping, Google Earth Imagery, KFA and site plan.

Note that for Average soil thickness (cm) for KSA (>200, 101-200, 51-100, 20-50, <20, Bedrock), this question is related to the overall sensitivity of the karst landscape and is typically available from the site plan. This measure includes all organic and mineral soil layers above bedrock. If this information is not available from the site plan, it should be determined in the field. This information can be very useful for future research about soil loss caused by disturbance on karst.

Regarding the Estimate of Karst Roughness for KSA (Low, Moderate, High, Very High), this question is related to the overall sensitivity of the karst landscape and can be determined from the visual image on karst roughness (see Figure 24). This information can be gathered during or after examining the KSA in the field.

There is also road-related information that may be collected if there is time. Although optional, the information can easily be done by walking or driving roads in the field, and is useful for later analysis.



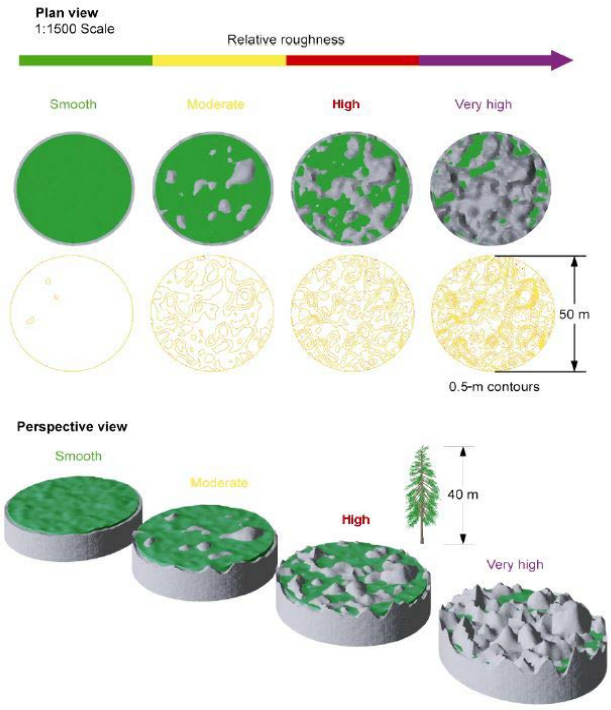
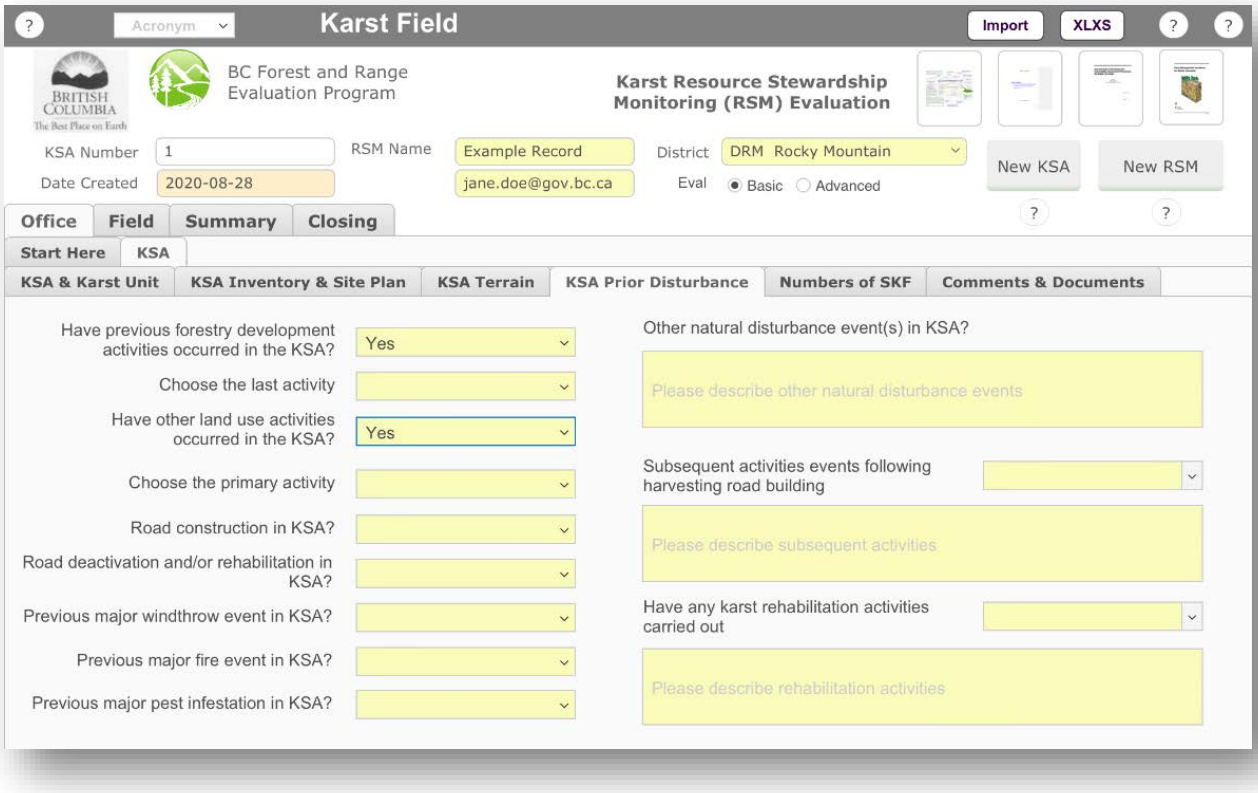


Figure 24: Visual Chart for Rating Karst Roughness

KSA and Prior or Post-Harvest Disturbance

The ***KSA Prior Disturbance*** tab focuses on whether there are any known previous or pre-harvest disturbances within the KSA. Some of these maybe indicated from site plan information, whereas others may not be known until after the field work (e.g., fire and windthrow).



Number of Surface Karst Features

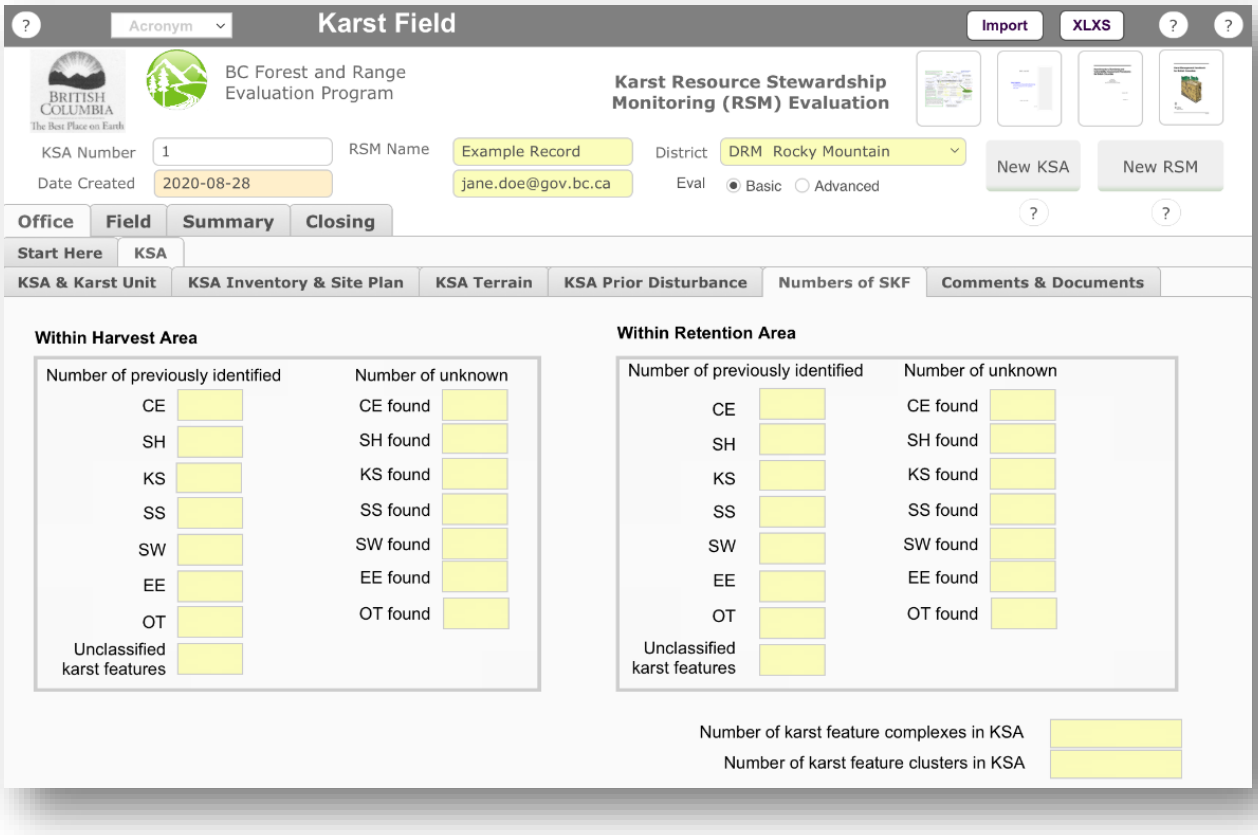
The ***Numbers of SKF*** tab is used before and following field work. During the office phase the number of the different types of previously known or identified SKF are listed based on the seven different types – CE, SH, KS, SS, SW, EE and OT. The number of Feature Clusters and Feature Complexes should also be estimated.

During the field work other SKF features might be encountered that were previously unknown. These are not to be evaluated, but tallied as unknown features found.

In many cases the types of known SKF are misidentified and so this page will need reviewing after the field work. Following the field work, the number of SKF types sampled, Feature Complexes, and Feature Clusters will be used to calculate the percent (%) sampling for the different types of SKFs (See summary table in the ***Summary/Surface Karst Feature Sampling*** tab).

Comments & Documents

The ***Comments & Documents*** tab is used to insert text, documents or photos relating to the KSA.



5.3.3 *Field /Surface Karst Features*

This part of the Karst field checklist focuses on surface karst features (SKFs), collecting baseline data on these features, answering disturbance indicator questions, and collecting information on these disturbances.

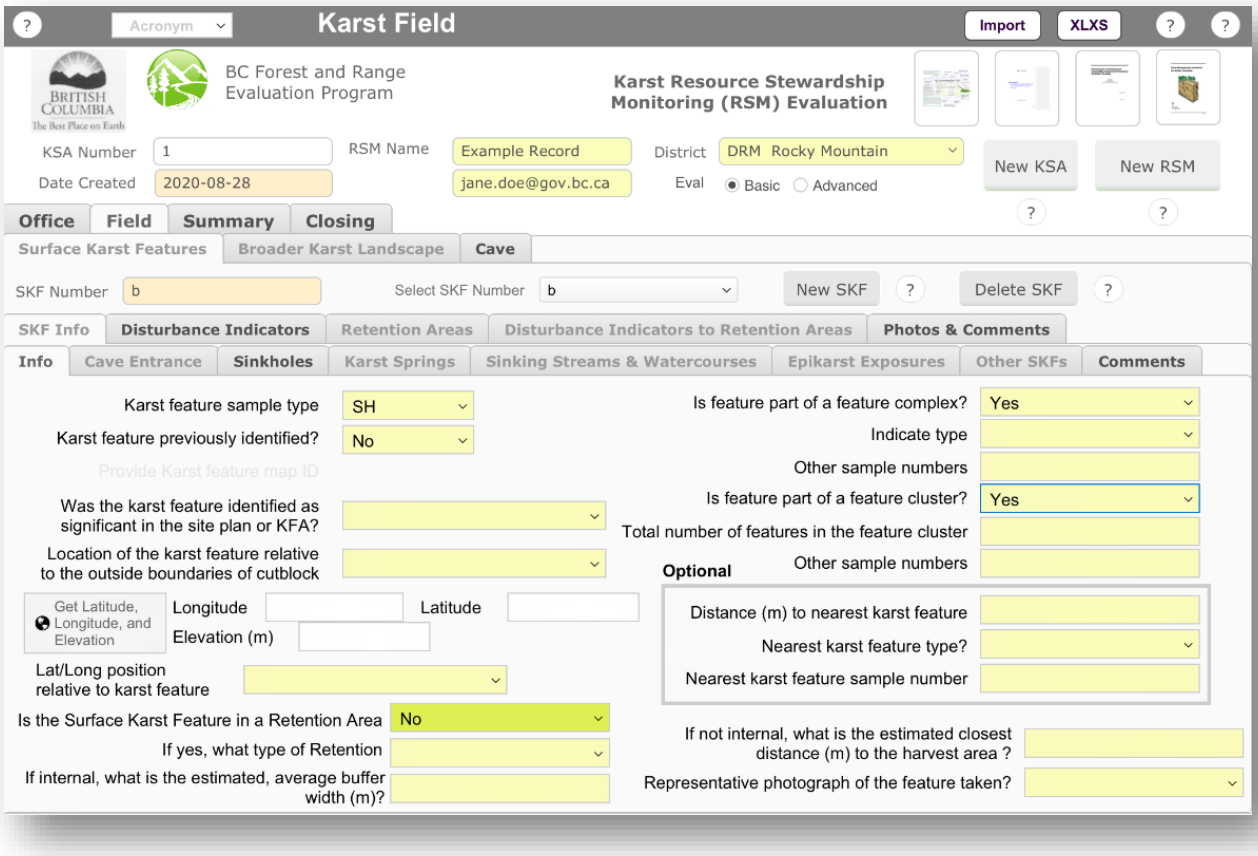
General Information on Surface Karst Features

General information on SKFs evaluated in the KSA is entered under the ***Field/Surface Karst Features/SKF Info/Info*** tab. A default SKF is started automatically. Information including the sample number, feature type, spatial location, and whether the feature is part of a Feature Complex or Feature Cluster is entered.

From the ***Field/Surface Karst Feature*** tab, click on New SKF to enter information on each additional Surface Karst Feature you evaluate.

The SKF sampled may be an individual feature (e.g., just a sinkhole SH) or a component of a feature complex. Categorizing the type of feature being sampled is critical as it will determine the measurements and information to be collected in the checklist. Select the "Karst feature sample type" on the ***Info*** tab (select from CE, SH, KS, EE, SS, SW, OT or Unclassified). Additional details on how karst features are classified can be found in Appendix D of KISVAP and Appendix 1 of the KMH.

The question "***Is the Surface Karst Feature in a Retention Area***" (yes/no) is used to group features in Harvest versus Retention so that comparisons can be made later.



Photographs are highly recommended as they can capture the appearance of karst features in a way that no description can. They can also confirm or clarify some of the data entry questions that might come up during data analysis. In the case of large sinkholes, it may be necessary to take wide angle [7]or composite photos from the rim. For sinking streams and sinking watercourses, an upstream view of the channel and riparian area from the downstream end of the sample segment is recommended.

The subsequent tabs, ***Cave Entrance, Sinkholes, Karst Springs, Sinking Streams & Watercourses, Epikarst Exposures,*** and ***Other SKFs*** are used to collect more specific information on a surface karst feature after it has been categorized to the pertinent "Karst feature sample type" on the ***Info*** tab.

The ***Photos & Comments*** tab can be used for each SKF to insert text, sketches (using "Signature"), photographs, documents, and even audio recordings.

[7] The ability to take wide angle image are particularly useful for sinkholes. The I-Pad may or may not have this function, but most Gold Pro cameras do. Filemaker Pro does have the ability to sketch so this can be used for features if required.

Feature Complexes

For complexes, use the prioritization described in Table 2 below to determine which component of the complex shall be evaluated. For each cluster, randomly select one feature from within to evaluate.

Table 2 – Sampling of Karst Feature Complexes

Karst Feature Complex Type	**Description**	**Sampling Order**	**Rationale**
CE/KS	Karst spring that emerges from a cave entrance	KS and then CE, preferably both	Water flow
CE/SH	Cave entrance at base of sinkhole	SH and then CE	Nested Feature
CE/SS,	Sinking stream that leads into a CE	SS and then CE, preferably both	Water flow
CE/SW,	Sinking watercourse that leads into a CE	CE and then SW	Management Priority
CE/OT,	Cave entrance at the base of a bluff	CE and then OT	Management Priority
CE/OT	Cave entrance at the base of a canyon	OT then CE, as likely more openings along canyon	Large Water Feature
CE/SS/SH,	Sinking stream that leads into a cave entrance located within a sinkhole	SS and then SH, possibly CE	Water flow and nested feature
CE/SW/SH,	Sinking watercourse that leads into a cave entrance located within a sinkhole	SH and possibly CE and SW	Nested feature and management priority
SW/SH,	Sinking watercourse into a sinkhole	SW and then SH	Water flow
SS/SH,	Sinking stream into a sinkhole	SS and then SH	Water flow
SW/OT,	Sinking watercourse into a grike	SW and the OT	Water flow
SS/OT,	Sinking stream into base of bluffs	SS and then OT	Water flow
SH/OT,	Grike at the base of a sinkhole	SH and then OT	Nested feature
EE/OT,	Grike in an epikarst zones	OT and then EE	Management Priority

** If the Karst Feature Complex type is not listed as above, use the following guidelines to prioritize which feature should be sampled:

1. For completely nested feature complexes, sample the outer feature. For, example with a cave entrance in a sinkhole, sample the sinkhole first.
2. For karst features that involve water flow (i.e., SS, SW, KS), evaluate these features first and then proceed to a CE if present, unless they are enclosed by a depression or SH as in 1
3. For EE areas that include OT or SH, sample the later first before the EE.

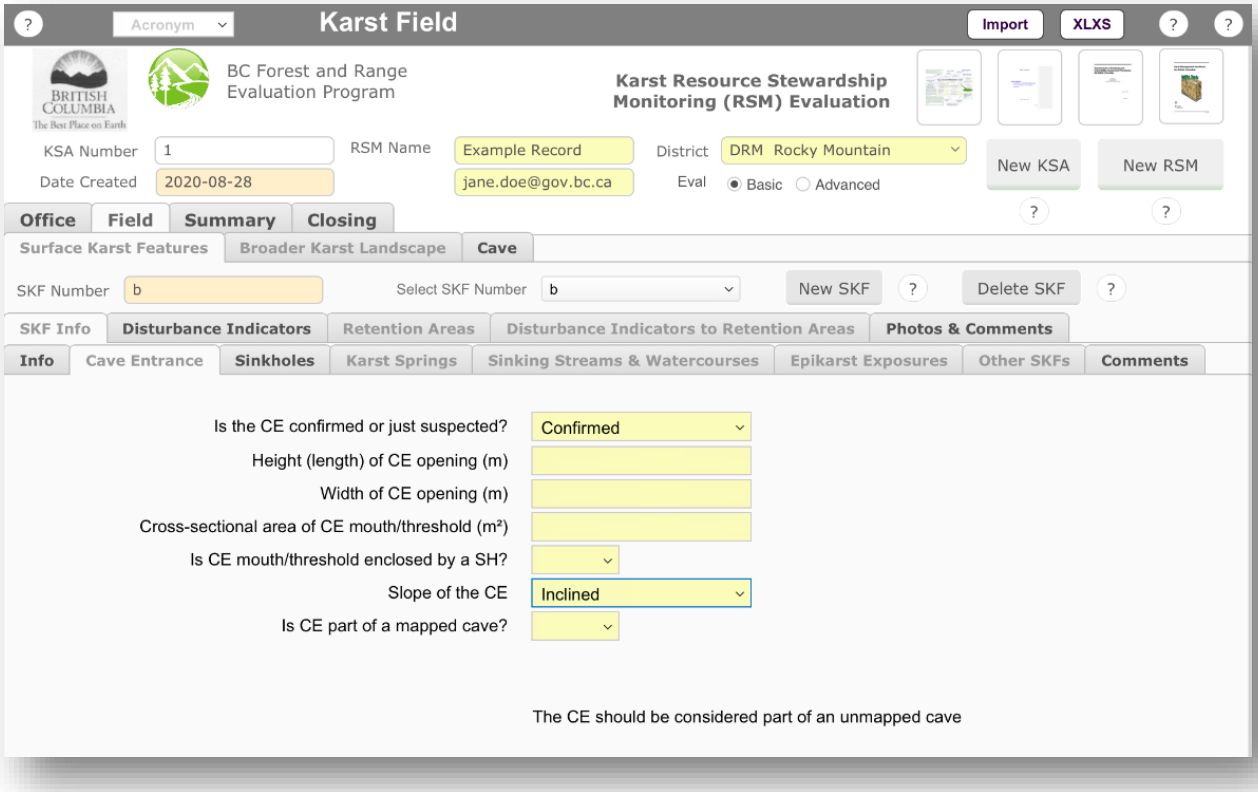
Cave Entrance (CE)

The ***Cave Entrance*** tab gathers basic information on a cave entrance so that it can be determined whether a Cave Evaluation is required. The information can also provide data for later analysis and reidentification of the site.

To answer the question: "*Is the CE confirmed or just suspected?*" (Confirmed, Suspected), it requires that someone with suitable subsurface experience must enter the suspected cave entrance and establish that there is a zone of total darkness and that it is a natural opening. If both conditions are

satisfied a cave is present and the cave entrance is confirmed. If this is not done it is a suspected cave entrance.

All CEs by default should have an associated cave, defined as having a zone of darkness that is accessible by a human. If the latter is not known it is a 'suspected' CE. If the nature and extent of the cave is known, and it has been confirmed by a qualified person, then the CE is a 'confirmed' CE. In this case a Cave Evaluation should be carried out.



Height and width measurements for the cave entrance are required to determine an estimate of the cross-sectional area of the cave entrance opening. This measurement is usually taken from the dripline of a horizonal/sub-horizontal cave entrance. For vertical cave entrances, there will be no drip line. Typically, the width and height of the cave entrance can be measured, and the area calculated depending on its shape (circular, elongate, triangular). Appendix 4 provides some typical formulas for area calculations. Note that this is an estimate only. Many caves entrances occur in sinkholes or enclosed depressions or are linked other features (e.g., at the base of karst bluff). In these cases, the details on these features should be collected, and their edges/rims determined for the disturbance evaluation purposes.

Sinkholes (SH)

The ***Sinkholes*** tab collects data on sinkholes, one of the most common surface features found on a karst landscape. The main details collected are the dimensions of the sinkhole using the sinkhole rim as a

reference plane. As a first step in the evaluation the sinkhole should be examined, and the rim defined using flagging to assist in identifying its location.

If the sinkhole includes a cave entrance this should be identified. If yes, it possible that the sinkhole rim acts as the edge of a cave entrance and it should be measured as such.

The length and width (or diameter) of the sinkhole should be measured to the nearest 0.1 m using the slope break at the sinkhole rim as a guide. It is important that the rim is carefully delineated, and flags laid out in the field at cardinal points of sinkhole can assist in this. Measurement of distances can be done with a tape or a handheld laser. If the sinkhole, or one side of the sinkhole is on a slope, then measurement is more difficult, as the rim or slope break might be further upslope.

The horizonal dimensions of a sinkhole are measured at the rim (or slope break; see Figure 25). In general, the greatest dimension is measured first and then a second one (the shortest if not circular) perpendicular to it.

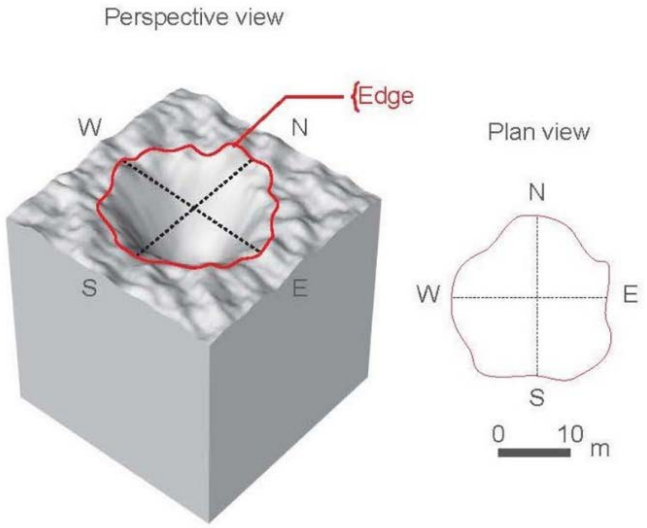
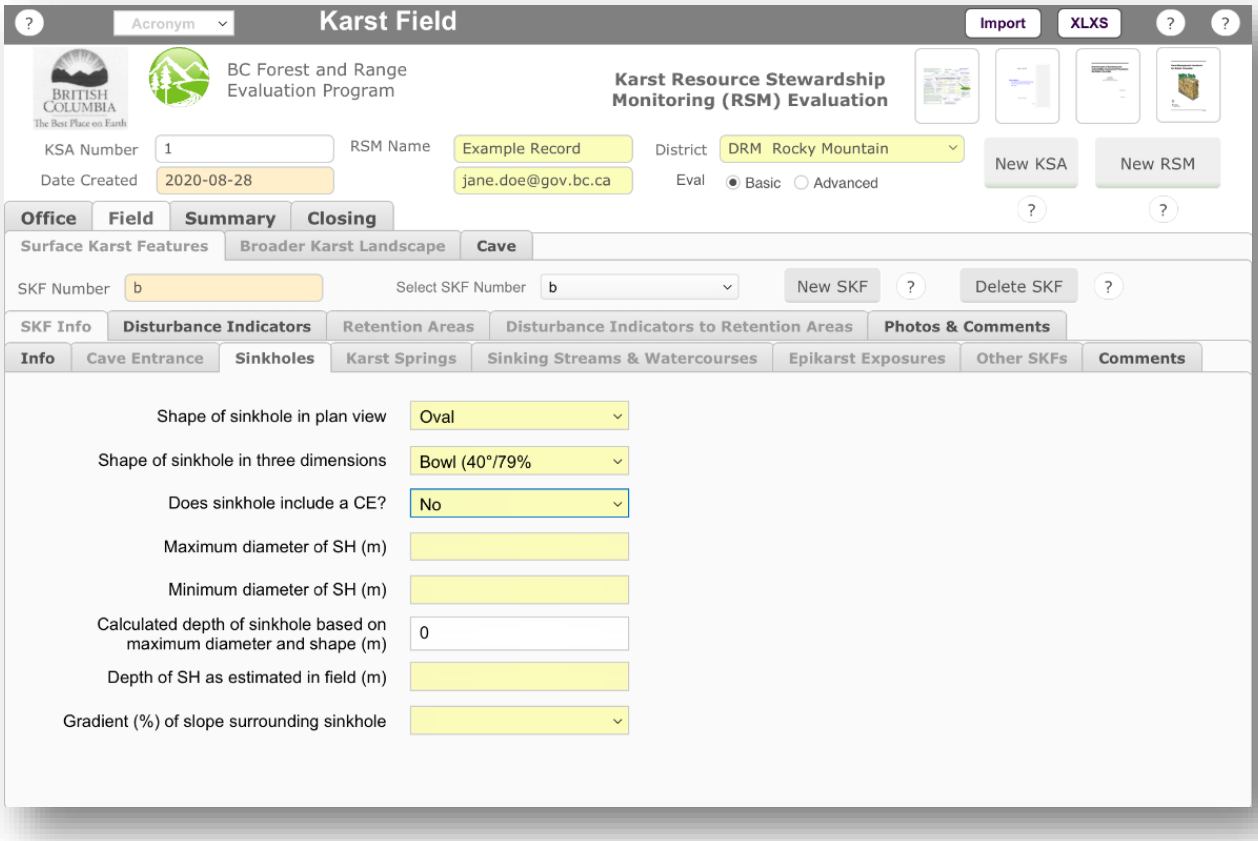


Figure 25: Defining the Rim of a Sinkhole - 3D perspective image shows the rim or edge of the sinkhole with N-S and E-W measurements. In most cases the maximum and measurements are enough for smaller sinkholes. Measurements using cardinal points might be useful for larger sinkholes and where surrounding retention areas are evaluated.



Karst Springs (KS)

Karst springs require measurement of the cross-section of the spring opening or outflow area. However, it also requires measurement of the stream that emerges from the spring, estimating the size and nature of the spring flow.

If the KS opening is large enough for a human to enter, it is potentially a cave entrance, although this may be difficult to confirm if water flow fills the opening. This question typically depends on whether a cave is accessible during low flow conditions[8]. If a cave is present then the KS is part of a complex feature, and consideration should be given to measuring the CE as well as the KS (see Table 3).

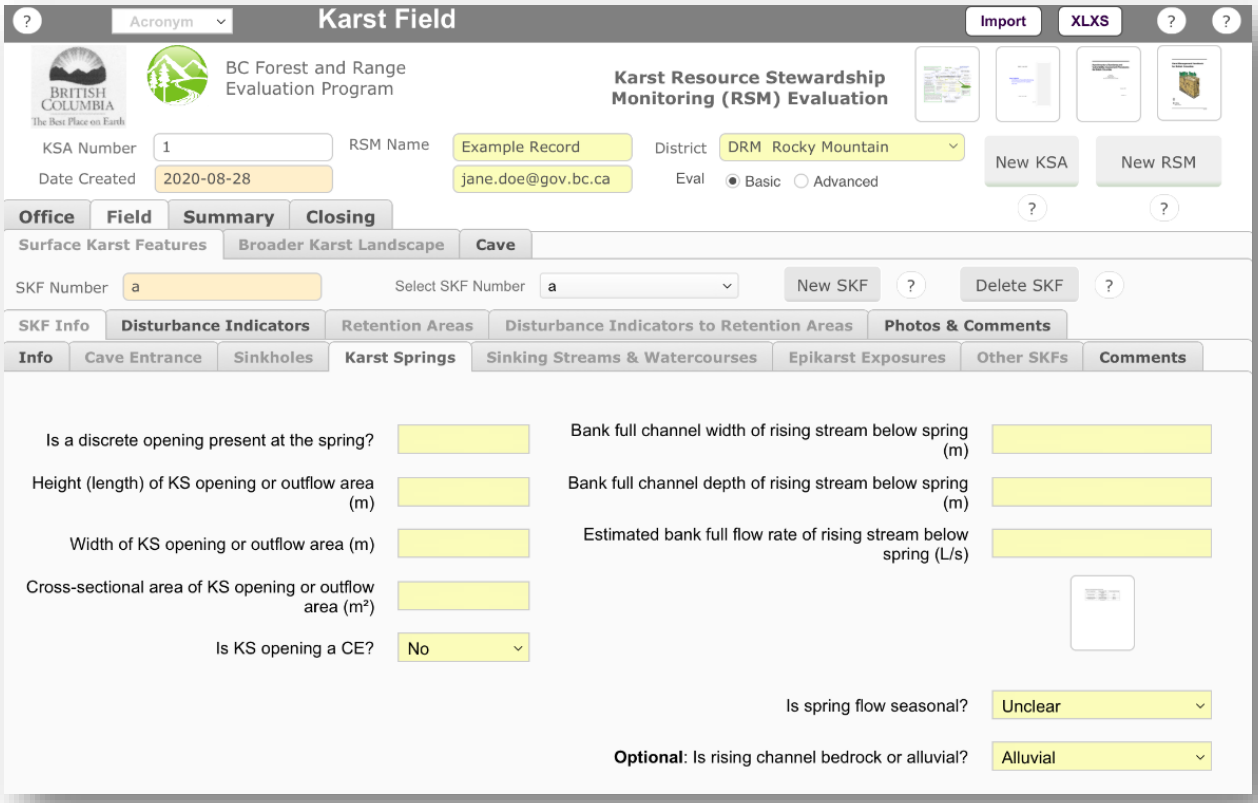
To estimate the bank-full flow rate of rising stream below spring (L/s), use Table 3 below as a simple method for estimating flow rate for the karst spring. This information is important as it can provide clues on the size of catchment associated with the spring.

Karts springs can also emerge out of enclosed depressions and if this is the case the rims of the depressions should be used for disturbance evaluation purposes rather than the karst opening.

[8] Caves can theoretically exist even if water-filled, and can be dived. However, this is well beyond the scope of this evaluation.

Table 3 – Estimates for Determining Discharge of Karst Springs

Ease of Crossing Stream	Estimate Time to Fill a Container	Estimate Bankfull Discharge
Can block the stream with foot	4 seconds to fill an ice cream container	1 L/sec
Can step across stream	4 seconds to fill a small fish aquarium	10 L/sec
Can jump across stream	2 seconds to fill a bathtub	100 L/sec
Can walk/wade across stream	2 seconds to fill a hot tub	1000 L/sec
Can walk on log across	10 seconds to fill a backyard swimming pool	10,000 L/sec



Sinking Streams (SS) and Sinking Watercourses (SW)

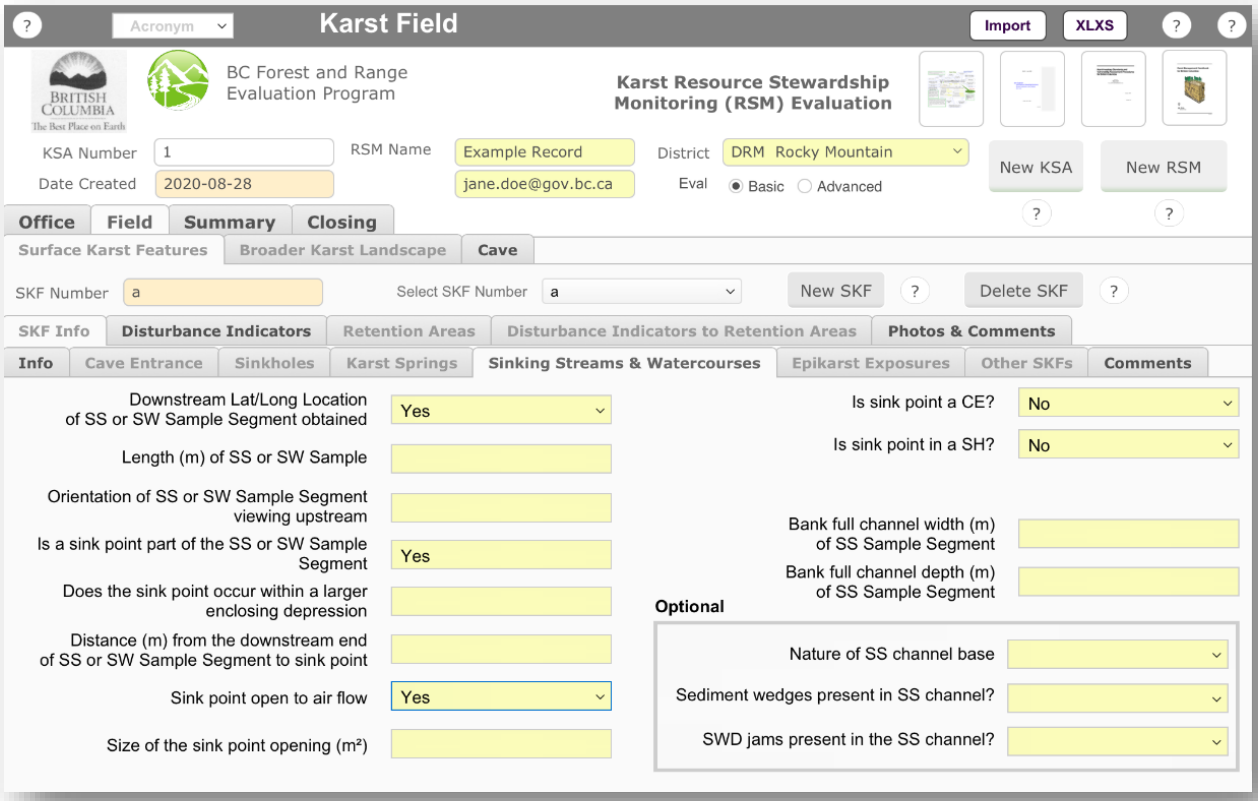
Sinking Streams (SS) and Sinking Watercourses (SW) should be examined over segments that are approximately 30-50 m in length. Typically, these features can occur near the karst unit boundary on both the non-karst and karst. In many cases the sink points of SSs and SWs mark the location of the karst unit boundary. As a first step, the SS or SW should be walked to identify: locations for width and depth measurements, presence of sink points and evidence for water loss or gain. The length of sample segment should be measured, and the upstream viewing orientation recorded.

The size of the sink point opening (m2), if present, is a cross-sectional area that can be determined from an estimate of width and height and the area calculated depending on its shape (circular, elongate, triangular). Appendix 4 provides some typical formulas for area calculations. This is an estimate only.

Possibly the sink point is part of a feature complex if the sink point is a CE or SH. If the sink point occurs in a SH there should be a clear enclosing depression with a rim, however, the rim may be lower in elevation where the stream or water course enters the sink point. If the sample SS segment includes a sink point and a sinkhole/enclosing depression, the later should be sampled rather than the stream itself, depending in part on the dimensions of sinkhole and length of the SS segment.

For SSs, bank-full channel width (m) of SS Sample Segment, and Bank-full channel depth (m) of SS Sample Segment should be measured to the nearest 0.1m and you may need to average 3-5 width and depth measurements.

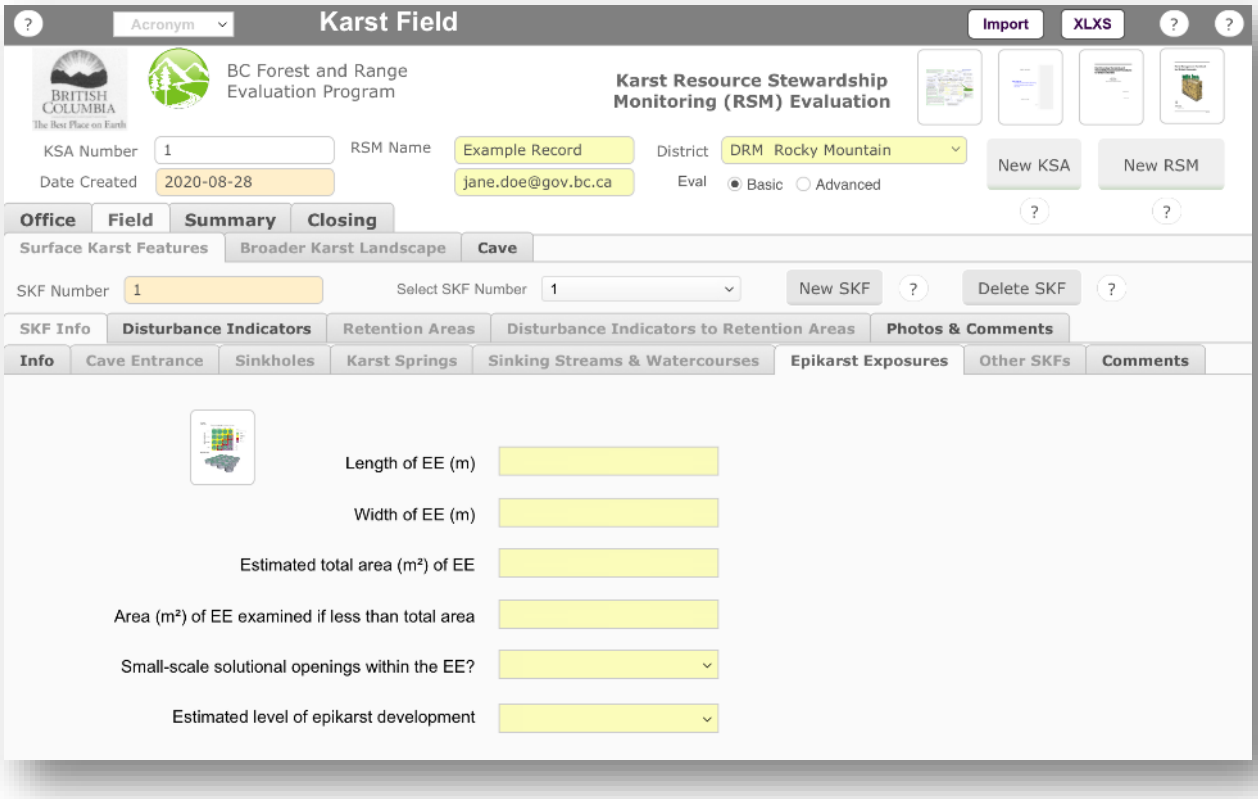
Supplemental information can be entered: e.g. the nature of SS channel base (Bedrock, Alluvial, Both, Unclear), whether sediment wedges are present, and for SW's, the width of the organic base. This information can be useful in providing indication of flow capacity and jams present in the channel.



Epikarst Exposures (EE)

Epikarst Exposures (EE) are elevated areas of epikarst where solutional weathering is exposed. Typically, they are covered with thin soil or forest floor material. The measurement of their extent maybe difficult,

particularly if the EE is extensive and or somewhat discontinuous. However, some arbitrary decision must be made as to its limits. This is best done by walking around the EE and if need be using flags to mark its extent. A sub-sample of the EE area can be selected if it is extensive.



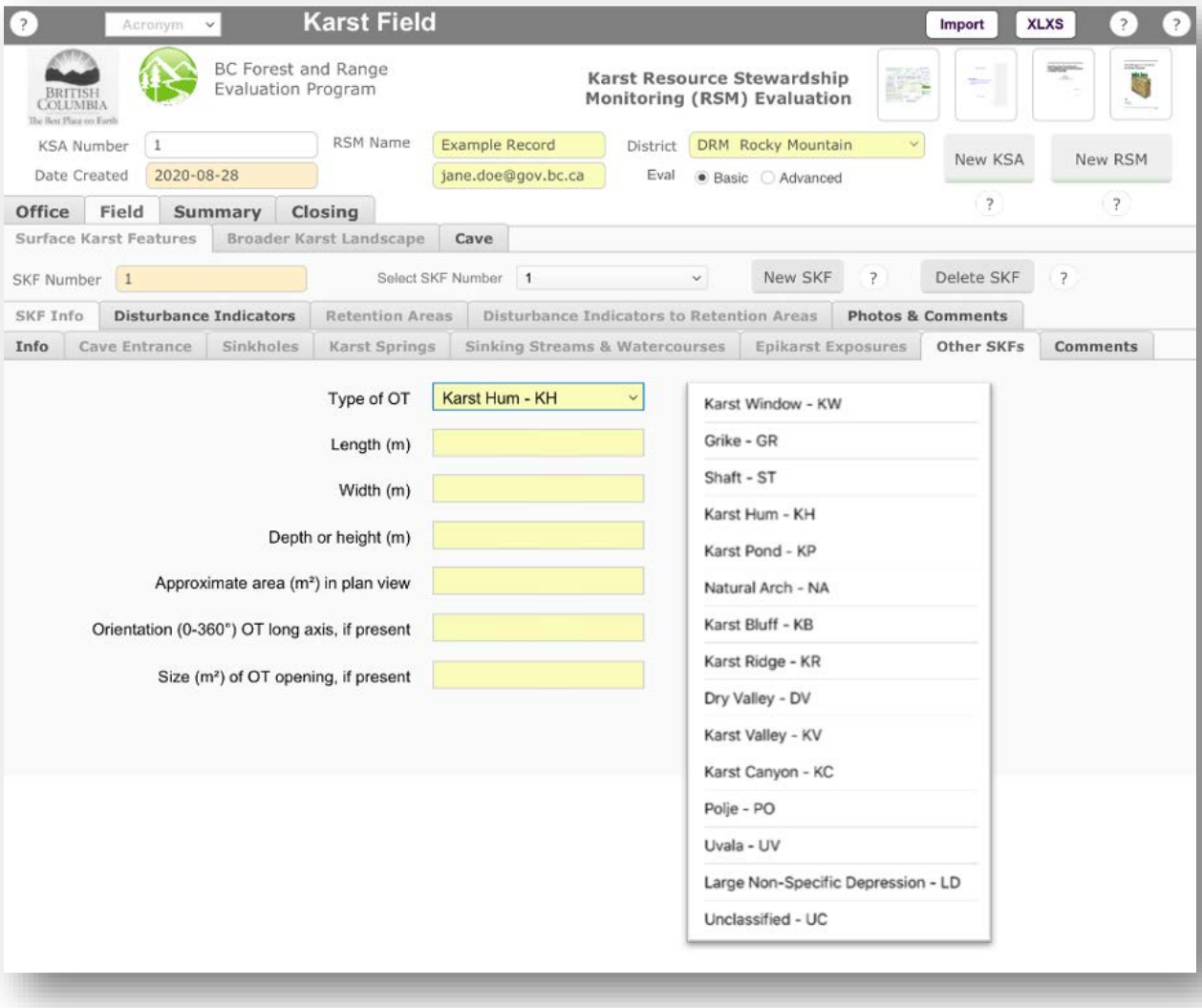
Other Surface Karst Features (OT)

Other surface karst features include a variety of shapes and sizes. Appendix 1 provides a flow chart that can be used be useful in identifying different karst feature types. This chart uses aspects of the feature including whether it has water flow, is a negative or positive relief, and whether is a point or linear feature.

Type of OT: (Karst Window - KW, Grike - GR, Shaft -ST, Karst Hum - KH, Karst Pond - KP, Natural Arch - NA, Karst Bluff - KB, Karst Ridge - KR, Dry Valley - DV, Karst Valley - KV, Karst Canyon - KC, Polje - PO, Uvala - UV, Large Non-Specific Depression - LD, Unclassified - UC) These are some of the most common surface karst feature types. If the feature is not in the list it can indicated as unclassified and the type added to the Comments Section for SKFs.

Dimensions of the features to the nearest meter are to be recorded for smaller features, to the nearing 5-10m for larger features. In some cases, these dimensions may have to be estimated from mapping information.

Where the size (m^2) of an OT opening needs to be recorded, this cross-sectional area can be determined from an estimate of width and height and the area calculated depending on its shape (circular, elongate, triangular). Appendix 4 provides some typical formulas for area calculations. This is an estimate only.



5.3.5 *Field / Disturbance Indicators* – Surface Karst Features

Collecting disturbance indicator data on surface karst features is an important part of the FREP Karst Evaluation, as it provides information on the state of their environmental condition and is part of the methodology used to assess the effectiveness of recent forest management activities. Disturbance indicator questions are applicable to the whole of the SKF including the 2 m envelope (zone) that extends from the edge of the feature outward (see Section 2.4, 2-Metre Measurement Zone). This 2 m zone is measured outward from the: rims of SHs, the opening or outflow area of KSs, the driplines or enclosing depressions of CEs, either side of the channel banks for SSs, center of the watercourses for SWs, and from the approximate edges of EEs and OTs.

In total there are eight disturbance indicator questions for each surface karst feature examined (see Table 4 Questions 1 to 8).

Table 4 – Disturbance[9] Indicator Questions for FREP Karst Evaluation

Surface Karst Features
Q1 - Were any trees[10] removed from the karst[11] feature?
Q2 - Is there any new windthrow at the karst feature?
Q3 - Has any road material or logging slash been introduced into the karst feature?
Q4 - Has any disturbance to the forest floor, mineral soil or bedrock occurred at the karst feature?
Q5 - Has any recent burning occurred at the karst feature?
Q6 - Is there a change in natural shade at the karst feature?
Q7- Is there a change to the understory vegetation at the karst feature?
Q8 - Is there any evidence of any previous disturbance at the feature?
Retention Areas Surrounding Surface Karst Features (Advanced Evaluation)
Q9 - Were any trees removed from within the Retention Area for safety, forest health or other reasons?
Q10 - Has any new windthrow occurred within the Retention Area?
Q11 - Is there any disturbed forest floor or mineral soil within the Retention Area?
Q12 - Is there evidence of recent burning (fire disturbance) within the Retention Area?
Broader Karst Landscape (Advanced Evaluation)
Q13 – Have trees been removed from the BKL Sample Plot?
Q14 - Is there any new windthrow in the BKL Sample Plot
Q15 – Is there any disturbed forest floor, mineral soil or bedrock in the BKL Sample Plot?
Q16 – Is there any introduced material within small-scale surface karst openings of the BKL Sample Plot?
Q17 - Has any recent burning occurred in the BKL Sample Plot?
Q18 - Is there any evidence of any previous disturbance in the BKL Sample Plot?
Cave Infiltration Areas (Advanced Evaluation)
Q19 - Were any trees removed from the Retention Area?
Q20 - Is there new windthrow in the Retention Area?
Q21 - Is there any disturbed forest floor or mineral soil in the Retention Area?
Q22 - Is there any evidence for recent burning in the Retention Area?

Seven of the questions relate to the various types of recent disturbances, primarily forestry-related, that can affect karst features at the surface and potentially impact subsurface karst. The eighth question examines previous disturbances to surface karst features. These disturbances may influence how a karst feature functions, and potentially could have had a greater impact than more recent disturbances. The different disturbances may overlap, but are addressed separately. In some cases, recent disturbances may contribute to cumulative impacts when compounded with the effects of previous disturbances

[9] All disturbances in the indicator questions should refer to recent forestry-related disturbances (not "old" disturbances, pre-harvest) unless specifically indicated as something different.

[10] Trees in all indication questions refer to mature trees with a DBH > = 12.5cm

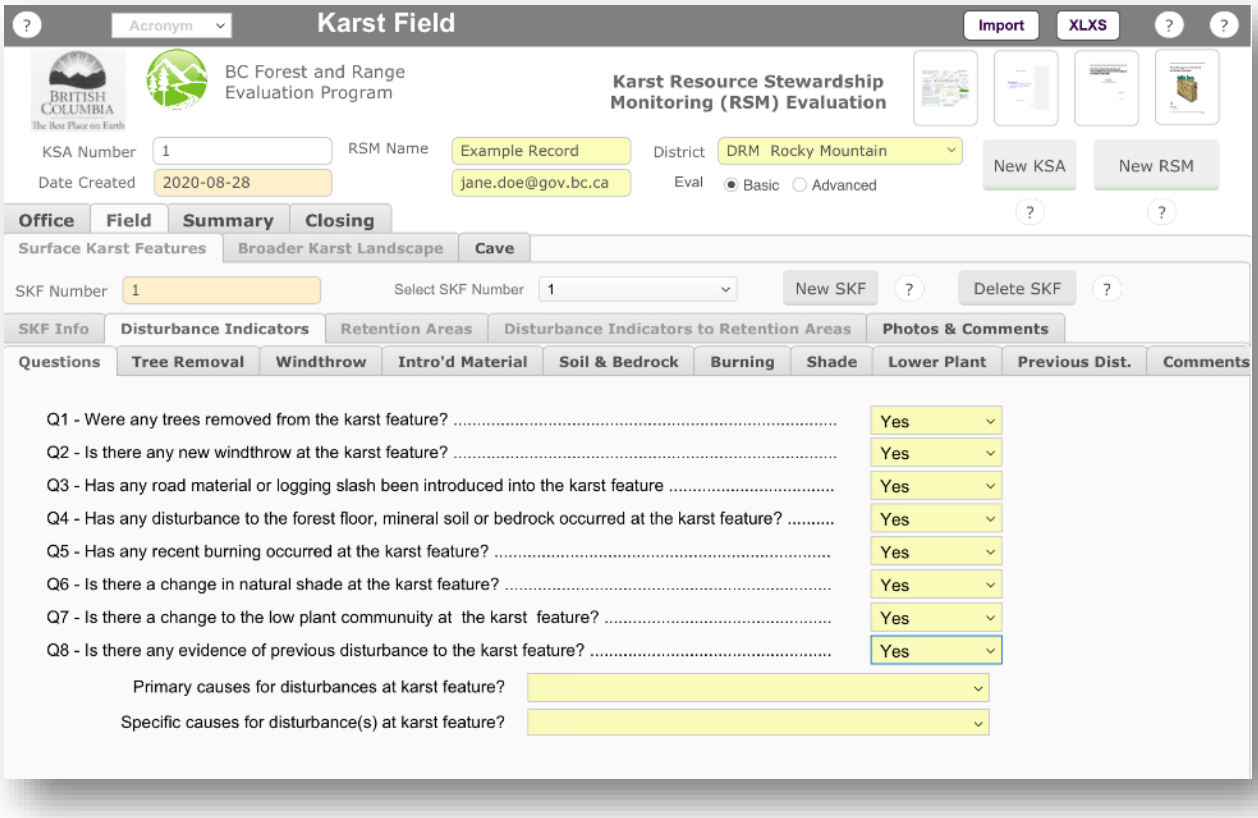
[11] The term 'karst feature' in the indicator questions refer to any of the surface karst features.

(e.g., a sinkhole infilled with logging debris during first-pass logging, with additional debris added from a second harvest.)

Disturbance Indicator Questions for Surface Karst Features

In all cases either a 'Yes' or 'No' response is required for the eight disturbance indicator questions as identified on the ***Disturbance Indicators/Questions*** tab[12]. A 'Yes' response indicates that a disturbance is present at the site. The rationale for providing a 'Yes' response is based on the premise that it is 'clear and obvious', such that another assessor with similar training and experience would come to the same conclusion.

At the bottom of the ***Disturbance Indicators/Questions*** tab, there are two questions that relate to the cause of the recent disturbance at the karst feature. The 'Primary cause of the disturbance at the karst feature' can be forestry activities, natural disturbances, other development activities or unclear. In almost all cases the answer to this will be 'Forestry Activities' as that is the focus of the FREP Karst Evaluation, however, there may be circumstances where 'Forestry and Natural Disturbances', and 'Other Development Activities'. A choice of 'Specific causes for the disturbance at the karst feature' can be selected, and may help in answering the closing questions (***Closing*** tab) of the FREP Karst Evaluation that related to karst management.



[12] A 'Blank' response does not imply a 'No' response but indicates that question has not been answered.

Under the ***Disturbance Indicators*** tab, there is a tab for each type of disturbance: ***Tree Removal, Windthrow, Into'd Material*** (Introduced Material), ***Soil & Bedrock, Burning, Shade, Lower Plant, Previous Dist.*** (Previous Disturbance). A ***Comments*** tab is also provided.

Determining the causes of windthrow is problematic, particularly when attempting to differentiate between windthrow caused by forestry activities or natural causes. Careful judgement is required. As a general guide, any windthrow along the edge of a cutblock or within a retention area is likely forestry related, particularly if windthrow is not apparent in adjacent forested areas. The assessor should consider whether the windthrow would have occurred if the cutblock or retention area was not present. More endemic windthrow covering a larger area might be attributed to natural causes.

Tree Removal at the Surface Karst Feature

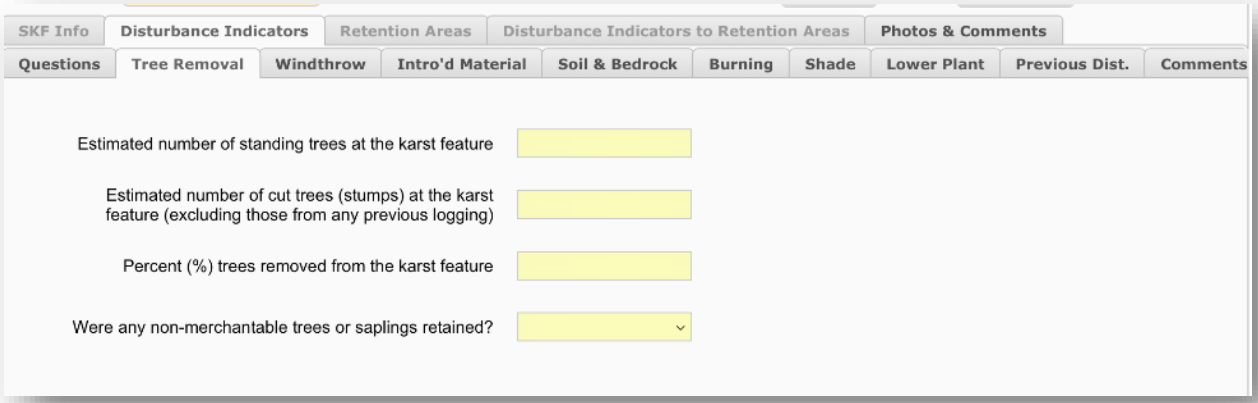
Q1 - Were any trees removed from the karst feature?

This question focuses on mature tree cover (> 12.5 cm DBH[13]). Tree cover is an integral part of the hydrological and ecological functions of karst systems. Removal of tree cover from karst features will lead to a variety of disturbances, such as changes to water infiltration rates, shade conditions (temperature/humidity), and flora and fauna habitat. A 'Yes' response to this question is appropriate even if one tree is removed from the site. (Removal also includes a tree that is cut and left on the ground). Note, even if the response to this question is 'No' it is still important to estimate the number of trees around the feature as this is useful information. In some cases, karst features may naturally have no trees around them.

The percent (%) trees removed is auto-calculated as per the formula:

% Trees Removed = Recently Cut Trees/(Recently Cut Trees + Standing Trees) x 100

For larger features (e.g., a 40 m diameter sinkhole) it may appropriate to count a sub-sample (e.g., just one quadrant of a large sinkhole). Old stumps from previous harvest at the feature are not counted but will be included as part of Q8 on previous tree removal.



[13] Trees greater than 12.5 cm DBH (Diameter at Breast Height) are typically considered mature trees in BC.

Windthrow at the Surface Karst Feature

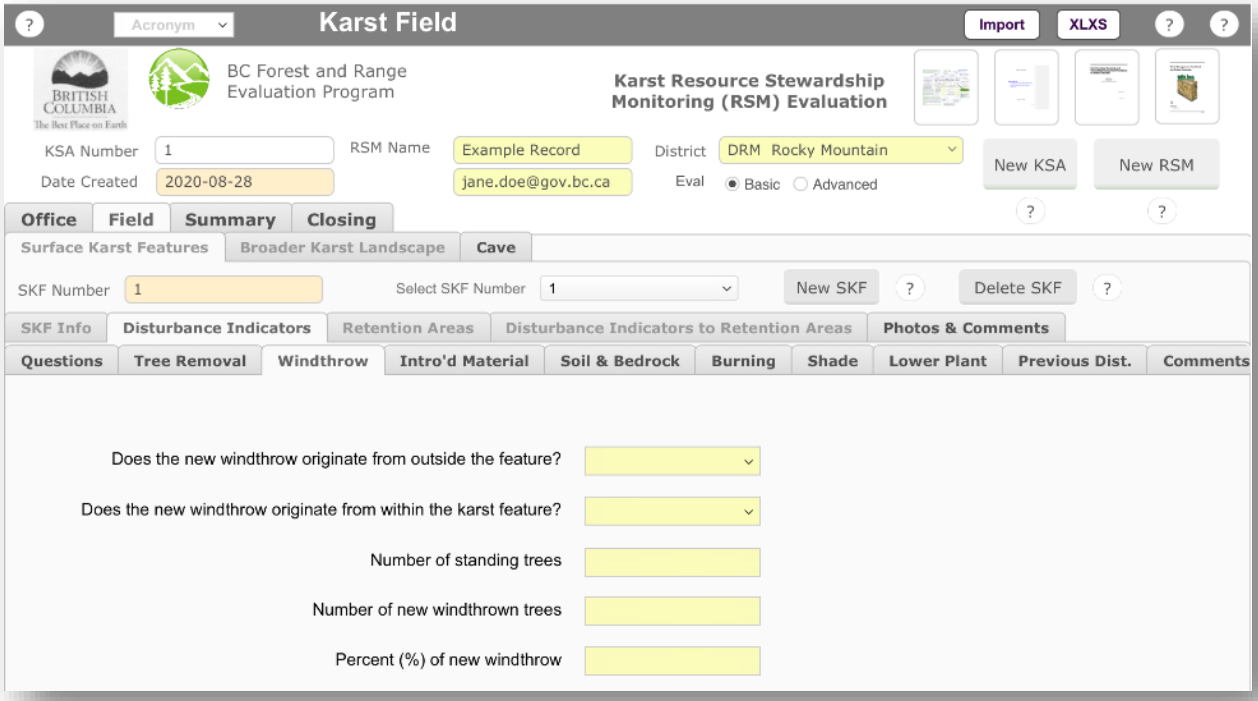
Q2 - Is there any new windthrow at the karst feature?

This disturbance question examines recent windthrow of mature trees (>12.5 cm DBH) at the SKF. Windthrow may occur from trees being uprooted at the karst feature, from nearby trees that have been uprooted and then fell onto the feature or from both. The former is likely to result in direct changes to the feature such as exposing mineral soil, loss of canopy cover, and altering hydrological functions. The second will primarily result in infilling of the feature with woody debris. A 'Yes' response to this question would be appropriate even for one windthrown tree occurring at the site. It would not include trees that suffered wind snap or breakage debris that has fallen on to feature.

The proportion of new windthrow is auto-calculated as per the formula:

% New Windthrow = New Windthrow within karst feature / (New Windthrow within karst feature + Standing Trees) x 100

Windthrow may or may not influence shade alteration depending on the proportion and spatial location of the windthrow. Windthrow associated with uprooting and tree rotation will likely disturb the forest floor material and potentially expose mineral soil or bedrock. If this disturbance occurs the zone of influence of the karst feature it is recorded as a 'Yes' for Q4 and the appropriate data collected.



Introduced Material at the Surface Karst Feature

Q3 - Has any road material or logging slash been introduced into the karst feature?

Refer to the ***Intro'd Material*** tab. This question asks whether any material has been added into the feature. Introduced materials mainly consist of two types: road construction material and logging slash. Road construction material can range from large angular blocks from road fill, to fly rock and fines from ditch lines or culverts (see Figures 25 and 26). Slash can include logs, splinters or chips, tree branches and tops, uprooted stumps, and broken or uprooted trees or shrubs. Looking for saw cuts on downed wood can easily identify logging slash (see Figures 27 and 28)



Figure 25: Fly Rock Material Infilling a Small Sinkhole



Figure 26: Fine Sediment Entering a Sinkhole on Side of Road



Figure 27: Logging Slash and Road Construction Material in a Sinkhole



Figure 28: Logging Slash Concentration in a Sinkhole

Two sub-questions are used to determine whether one or both types of introduced material types are present, and to assess their respective percent coverage of the SKF. In most cases, it is the finer woody material and sediment that is a concern to karst features, as this can infiltrate downward through openings and hydrological links into the subsurface. Excessive concentrations of materials can also alter hydrological and/or ecological functions of surface karst features.

Percentages can be estimated visually, by using a percent chart if need be (Figure 29). Ranges are provided to aid in more rapid determination. It is acceptable that these data be recorded to the nearest 1% up to 10%, nearest 5% up to 50%, and nearest 10% up to 100%. In most cases, drop down menus are provided giving options for percent ranges.

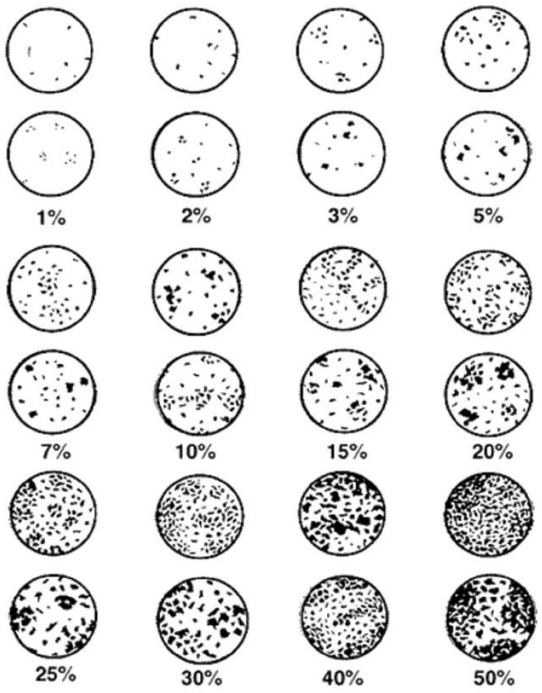
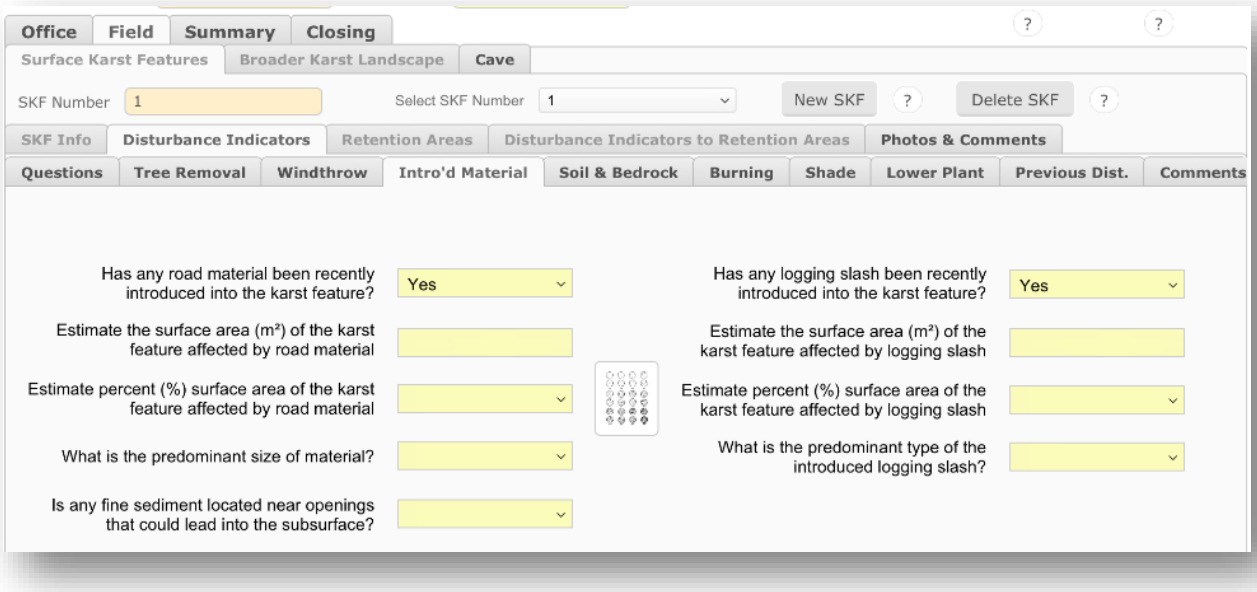


Figure 29: Visual Chart for Estimating Percentages.

The question: “Is any fine sediment located near openings that could lead into the subsurface?” is important in terms of potential impacts and disturbances to the subsurface and may require specific comments.



Disturbed Forest Floor, Mineral and Bedrock at the Surface Karst Feature

Q4 - Has any recent disturbance to the forest floor, mineral soil or bedrock occurred at the karst feature?

This question focusses on the non-living materials (forest floor, mineral soil and bedrock) in and around the karst features. Disturbance can occur when the forest floor is compacted or rutted during harvesting activities without exposing bare mineral soil. For example, ground based machinery can inadvertently create ruts around the rims of sinkholes directing surface flow into the feature. Skid trails can occur over/or near to the surface karst feature. Disturbed ground can damage vegetation such as: mosses, lichens or liverworts. Mineral soil can be exposed and/or disturbed is during forestry activities. This can occur during road construction, harvesting (e.g., dragging of cables, skidder trails) or due to failures on steep slopes (e.g., sinkhole sidewalls). Soil exposed due to recent rotational windthrow should be included, as this windthrow can be within the feature or outside. Exposed bare soil is susceptible to erosion movement into the openings of the feature, thereby affecting hydrological and ecological functions, and potentially transporting material into the subsurface (see Figure 30).



Figure 30: Exposed Mineral Soil on Side Slopes of a Logged Sinkhole

Bedrock can be exposed or mechanically broken when machinery, cables or other harvesting activities has physically interacted with bedrock. This commonly occurs on EE but can also occur on other exposed bedrock highs or around other types of karst features where bedrock is present. Recently exposed bedrock can occur due to sloughing on the edges of karst joints, fissures and other solutional openings. It is also seen on the tops and shoulders of raised karst bedrock elements bordering vertical or sub-vertical solution openings and hollows (see Figures 39 and 40). On some karst bedrock surfaces the mineral soil cover is very thin and might be no more than an inorganic grit under the forest floor. However, this forest floor an important part of the karst system, supporting plant growth, moss and

allowing water infiltration. Recently uncovered bedrock surfaces can be identified by changes in colour on bedrock surfaces. The data that is collected with a 'Yes' response to this question is as follows:



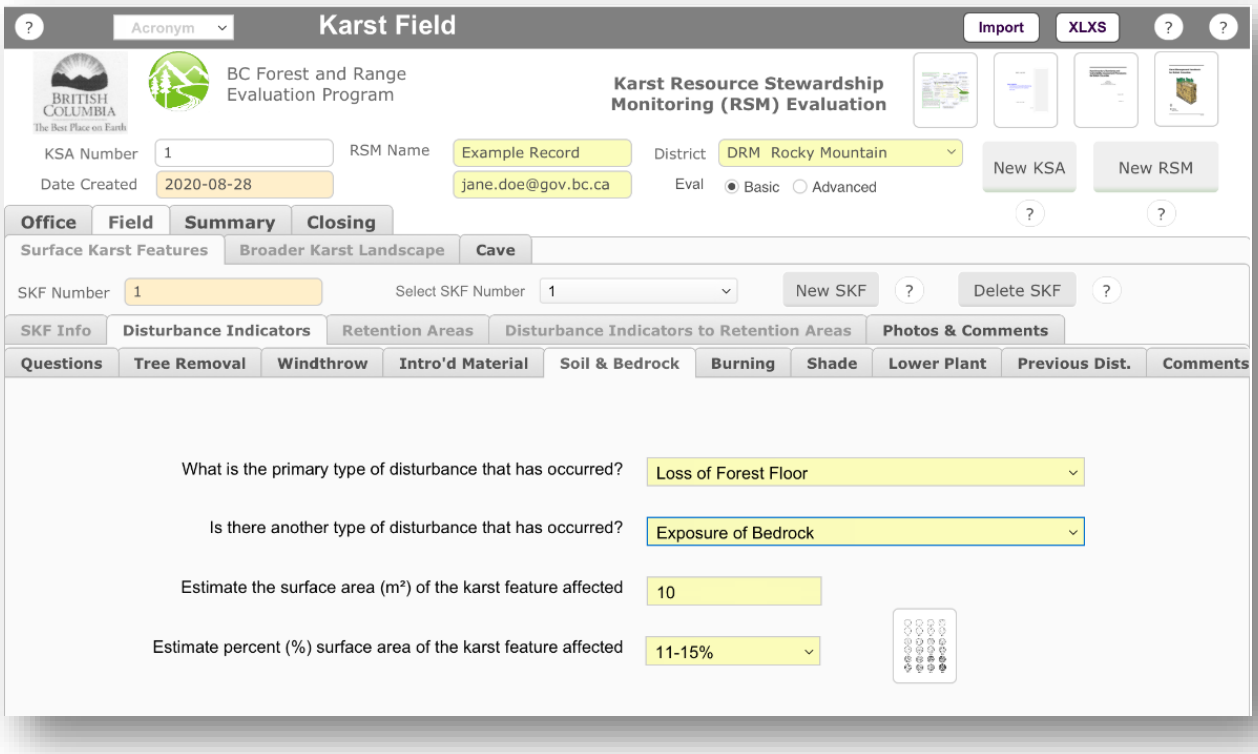
Figure 31: Exposed Bedrock and from Disturbed Mineral Soil and Forest Floor



Figure 32: Blasted and Broken Bedrock on Edges of a Grike

For the question “What is the primary type of disturbance that has occurred?” (Compaction or Gouging of Forest Floor, Loss of Forest Floor, Exposure of Mineral Soil, Sloughing of Mineral Soil, Exposure of Bedrock, Mechanical Breakage of Bedrock, Other), if the type of disturbance is not listed or is more complex an explanation can be provided in the comments section.

For linear SS and SW segments, record the extent of bare soil exposed along both sides of the stream within 5 m of the channel sides and any sites that have direct hydrologically connections (e.g., exposed mineral soil on the side slopes of a sinking stream that occurs in gully)



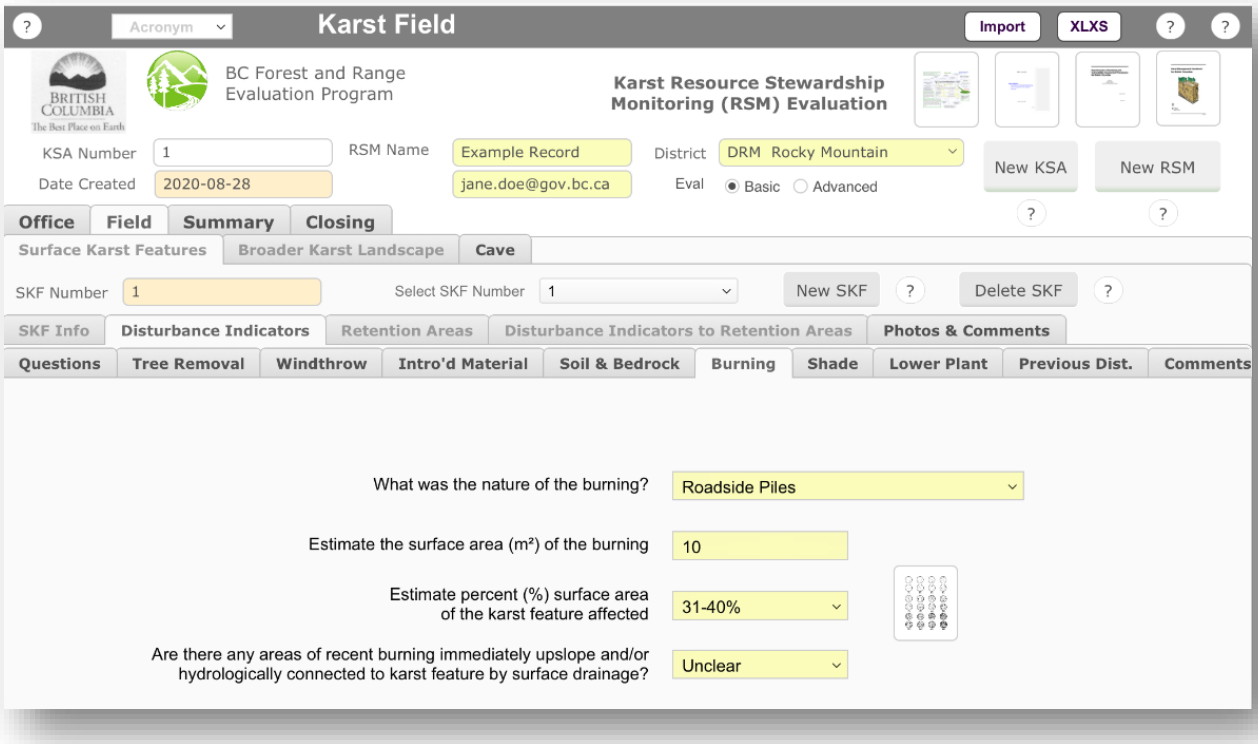
Burning at the Surface Karst Feature

Q5 - Has any recent burning occurred at the karst feature?

Burning (fire disturbance) at karst features can result in a several types of impacts. Soil and woody material can be carbonized, resulting in a fine ash material that can either be blown or transported by water into epikarst openings and eventually enter the subsurface (see Figure 41). Smoke can be transported subsurface during a burn event. In higher temperature burns, the limestone bedrock will undergo calcination and breakdown leaving a crumbling and friable lime powder on the surface. The chemistry of karst waters may also change. Flora and fauna at the site will also be impacted.



Figure 41: Burning Around Edges of a Grike



Shade Alteration at the Surface Karst Feature

Q6 - Is there a change in natural shade at the karst feature?

Refer to the ***Shade*** tab. Changes in shade should be considered in comparison to pre-harvest conditions and can have several effects on the feature such as varying microclimatic conditions (temperature and humidity) and altering flora and fauna habitat at the site. To assess whether the shade has changed at a site, stand at a representative location in or on the feature to be sampled. Visually recreate the pre-harvest conditions by "rebuilding" mature trees in the direction of the solar arc (viewing south and going from east to west). Include all the trees that may have been recently removed during or after harvesting. Shade alteration due to recent windthrow should be included. Remember to account for the absence of deciduous tree foliage if observations are made outside of the summer months. It

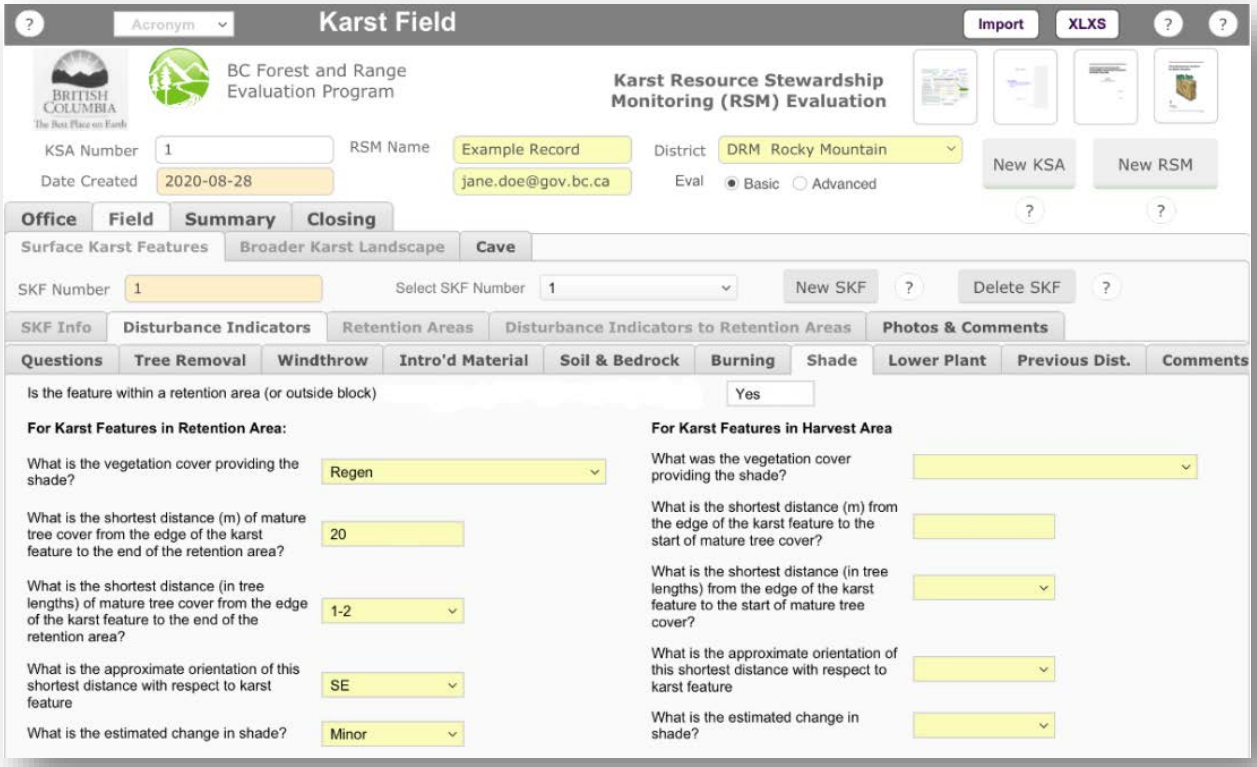
should be apparent in most cases as to whether shade has been changed or not. If all mature trees have been removed from within or on the edge of the feature, the shade has been totally changed (see Figure 42). If trees have been left at the feature, but the trees surrounding the feature have been removed, the shade level will have been changed. If an intact retention area has been left around the feature, the shade may or may not have changed, depending on a variety of factors, such as the location of mature tree cover with respect to the edge of the karst feature. As a general guide, <1 mature tree length would suggest some to considerable change in shade alteration, 1-2 tree lengths some to minor change, >2 tree lengths minor to none. However, the orientation and shape of tree retention around a karst feature and its position relative to the south-facing solar arc will also play a role in changes to shade.

Typically, on the west coast of BC, an average tree length for a mature tree is 30 m. This may vary from region to region.

The estimated change in shade is a subjective estimate using the shortest distance to mature tree cover from the edge of the karst feature (in meters and tree lengths), with consideration also given to whether tree removal has occurred within the southern solar arc.



Figure 42: Windthrow and Shade Alteration at Edge of Surface Karst Feature

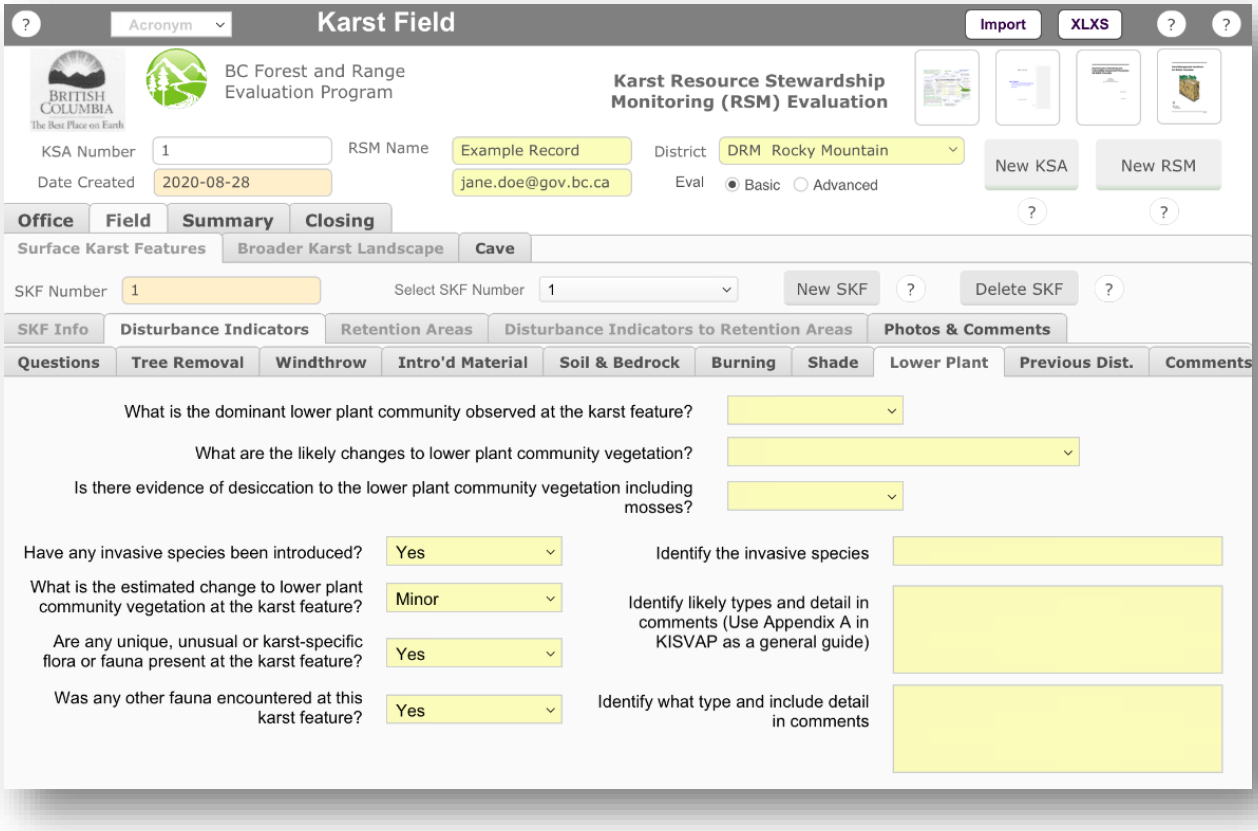


Lower Plant Community at the Surface Karst Feature

Q7 - Is there a change to the lower plant community at the karst feature?

Refer to ***Lower Plant*** tab. The purpose of Q7 is to determine whether the understory vegetation has noticeably changed at the SKF. If so, this could indicate some potential for alteration to the ecology at the site. Some karst features, such as cave entrances, large sinkholes with a distinct microclimate, and karst springs may have the potential for karst-specific flora and/or fauna (see Appendix A in KISVAP). Knowledge on the nature and extent of flora and fauna within karst systems in BC is limited, so the data collected for this question will also assist in better understanding these associations. Some of the sub-questions can be answered whether the response to Q8 is 'Yes' or 'No'. For a 'Yes' response there must be clear evidence of factors such as: mortality, extensive desiccation or invasive species. Comparison of the understory conditions to areas immediately next to the feature, as well in undisturbed areas nearby, can provide useful reference sites that will assist in answering this question.

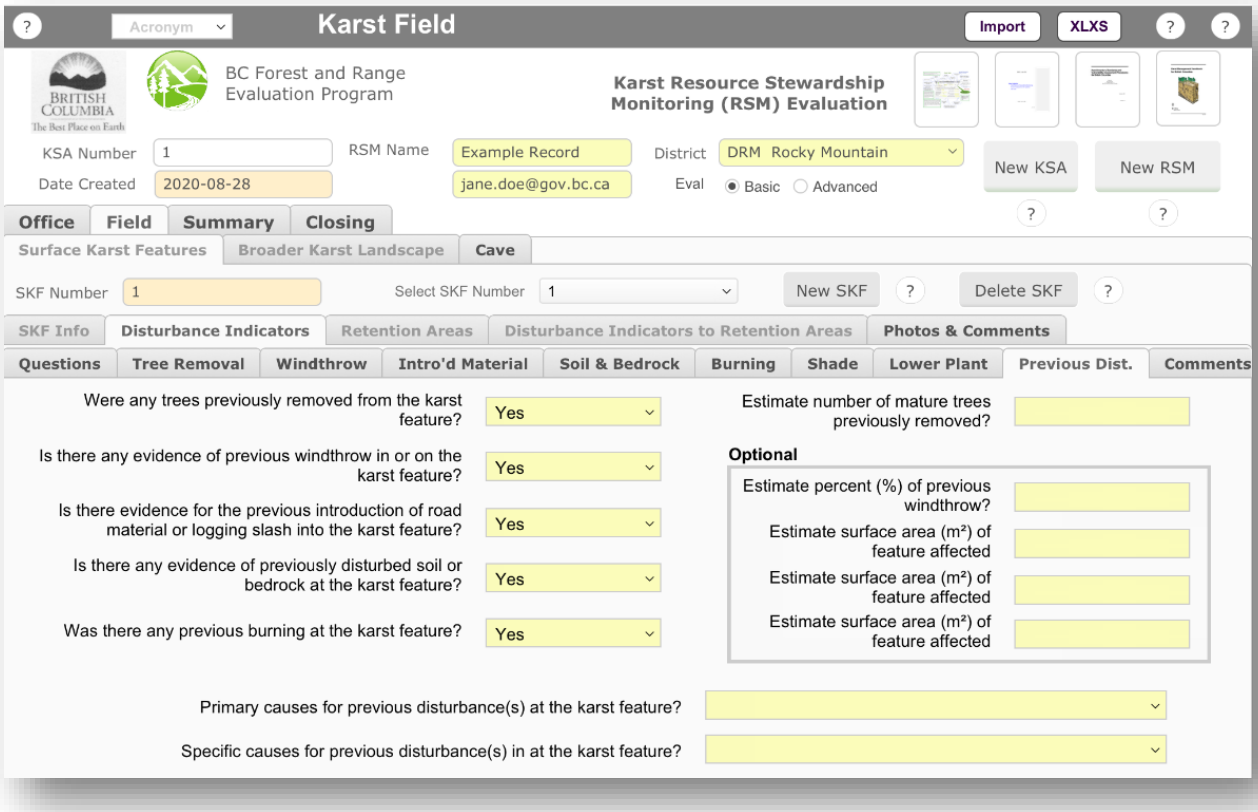
The estimated change to understory vegetation at the karst feature is a subjective estimate based on observations of the information gathered above. Comparison to nearby forested areas will assist in answering this question.



Previous Disturbances at the Surface Karst Feature

Q8 - Is there any evidence of previous disturbance(s) at the karst feature? (Yes, No)

Refer to ***Previous Dist.*** tab. Previous disturbance refers to "old" disturbance, or that which occurred pre-harvest. The purpose of Q8 is to determine whether previous disturbances had occurred at the karst feature and to assess their type and magnitude. Examination of previous disturbances can potentially be a difficult and lengthy process, and in some cases almost impossible to discern. Nevertheless, they are important to evaluate, as combined with recent disturbances, they can have a cumulative effect on the processes and functions of a karst feature.



5.3.6 *Field /Cave* – Cave Evaluations

Cave Evaluations are part of the Basic Karst evaluation procedure and are used to determine: whether a cave entrances (CE) identified in the KSA is linked to a known or suspected cave, whether the known caves in a KSA have been confirmed by a qualified person, if the known caves have been mapped, and if a Cave Infiltration Area (CIA) have been delineated.

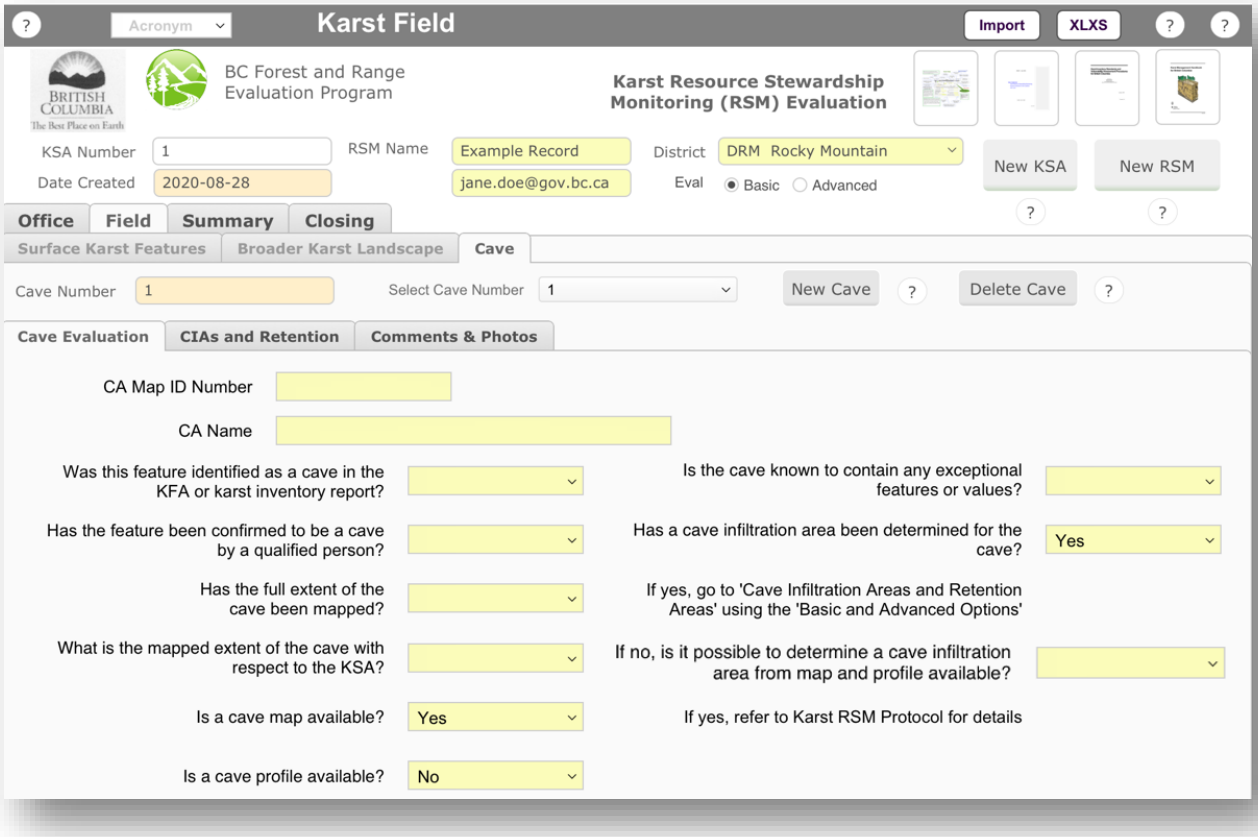
A feature identified as a cave entrance (CE) implies that it is linked to a cave, whose extent may or may not be known. This requires some form of confirmation. A CE linked to an unknown cave, is a 'suspected' CE. Confirmation of whether a cave is present can be determined from available information, such as the KFA report, cave maps, site plan. However, for a cave to be 'confirmed' it should have been examined in the field by a qualified person. It is typically beyond the scope of the Karst RSM assessor to confirm the presence of a cave, and no caves should be entered without experience of these environments.

During completion of a KFA caves that are encountered should be mapped to assess their location relative to the surface and assessed for their significance as outlined in Section 4.3.10 of KISVAP (RISC, 2003). Mapping should produce both a plan and profile to develop an idea of the three-dimensional extent of the cave. For this information it is possible to project their underlying location to the surface and define the extent the Cave Infiltration Area (CIA). The This is done by projecting a 45 angle from the edges of the cave openings up to the surface – see p.24-25 of the KMH. The overall intent of this CIA is to ensure there is no disturbance to the cave, particularly with respect to water infiltration. For

significant and shallow caves (defined as where the depth of the cave is <3 x the greatest dimension of the cave) this CIA should be developed as treed retention area or reserve, likewise for any significant cave with identified interior values (e.g., speleothems). However, for deep significant caves (where the depth is >3 x the greatest dimension of the cave) some management within the CIA maybe allowed. Any caves that have not been evaluated for significance should be consider significant until deemed otherwise. This is likely the general rule. If the CIA for a cave has been determined and located on a map, it is then possible to assess the extent and condition of the CIA. The CIA evaluation is considered one of the Advanced options of the FREP Karst Evaluation (See Section 6.3).

General Information on Caves

On the ***Cave*** tab, a blank cave record is already created. If you wish to add an additional cave, you can click on the New Cave button. The ***Cave*** tab collects general, information on caves and examines how cave entrances are related to caves, whether caves have been mapped or not, and if CIAs have been delineated.



6.0 Advanced Components

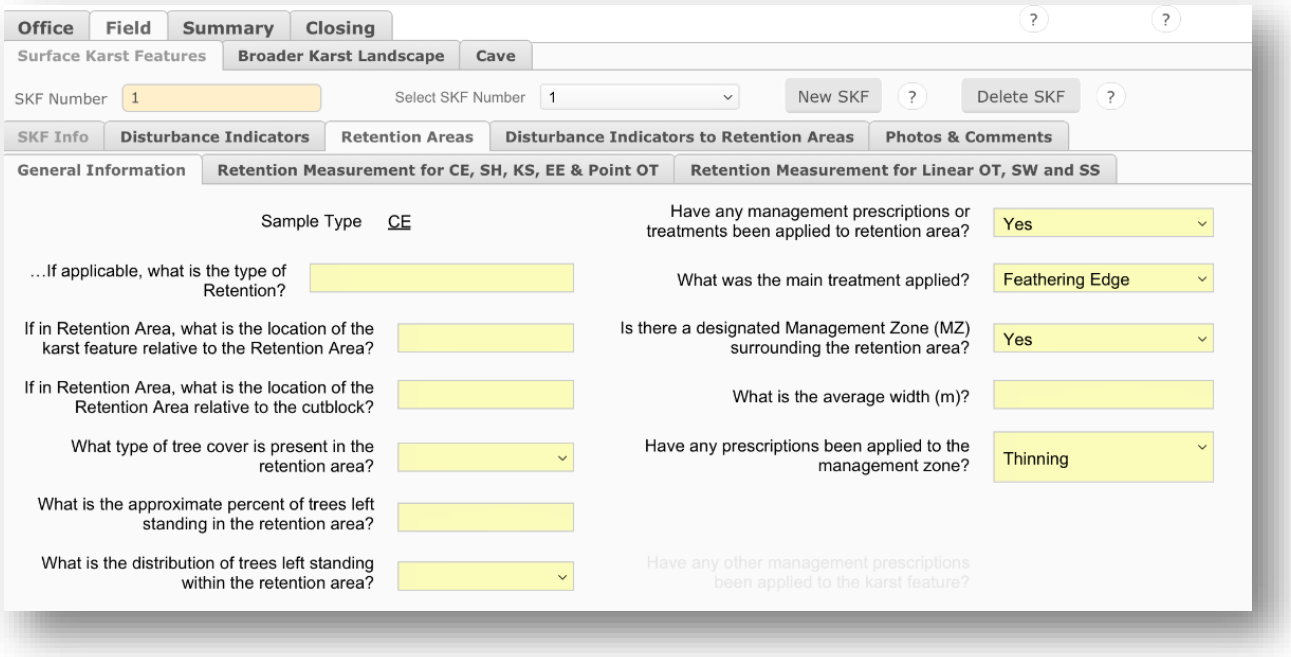
6.1 *Field/Retention Areas* – Retention Areas Surrounding Surface Karst Features

The examination of retention areas that surround SKF is one of the Advanced Options of the Karst evaluation procedure and is carried out in circumstances as determined by the district FREP lead.

Refer to the ***Retention Areas*** tab (located under ***Field/Surface Karst Features***). The methodology includes collecting information the characteristics and sizes of retention areas, and then evaluating their associated disturbances. Retention in karst management typically occurs where mature trees have been left surrounding a surface karst feature. The size of the retention area, location of the feature relative to retention area, and the percentage of trees left are all important questions in terms of how the retention area might function to protect the karst feature. Trees left standing within the feature are not considered retention (e.g., a sinkhole where trees have been left inside and along the rim). Likewise, where high stumps are left in and around a feature - this is not retention. In the Karst Management Handbook for British Columbia (KMH), retention is typically used in the forms of reserves and/or management areas surrounding karst features.

General Information on Retention Areas Surrounding Surface Karst Features

The data collected on the ***Retention Areas/General Information*** tab focusses on the location, purpose and nature of the retention area.



Retention Area Measurements for CE, SH, KS, EE & Point OT

Refer to the ***Retention Measurement for CE, SH, KS, EE & Point OT*** tab. The next set of data collected on retention areas are used to estimate its size in hectares (ha). The method of measurement might vary depending on whether the karst feature is a point or linear feature. Retention areas around point features (e.g., CE, SH, KS) would tend to be more equidimensional, as compared to those around linear

features (e.g., SS, SW), which would be more elongate. The distances of the retention area can be measured to nearest meter by using a laser distance meter, a hip chain, or tape. Visual estimates can be done by an experienced person; however, in this case reliability is probably reduced to the nearest 5 m[14]. This is acceptable when retention areas are larger in size (e.g., greater than 50 m). All measurements can be done by standing on the edge of the feature and facing the direction of measurement. In some cases, the retention area may extend for a considerable distance beyond the harvest area into unlogged forested areas. If so, a maximum number can be provided (e.g., greater than 100 m).

For retention areas around point feature like CE, SH, KS, EE & OT, the area is measured in a total of eight directions - the four cardinal and the four intermediates (see Figure 43). The reason for the eight measurements is to ensure enough data is available to calculate the approximate area in ha[15].

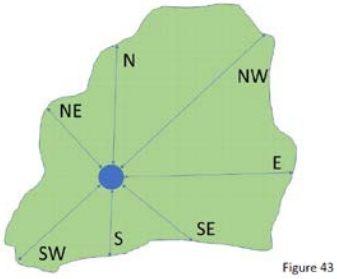
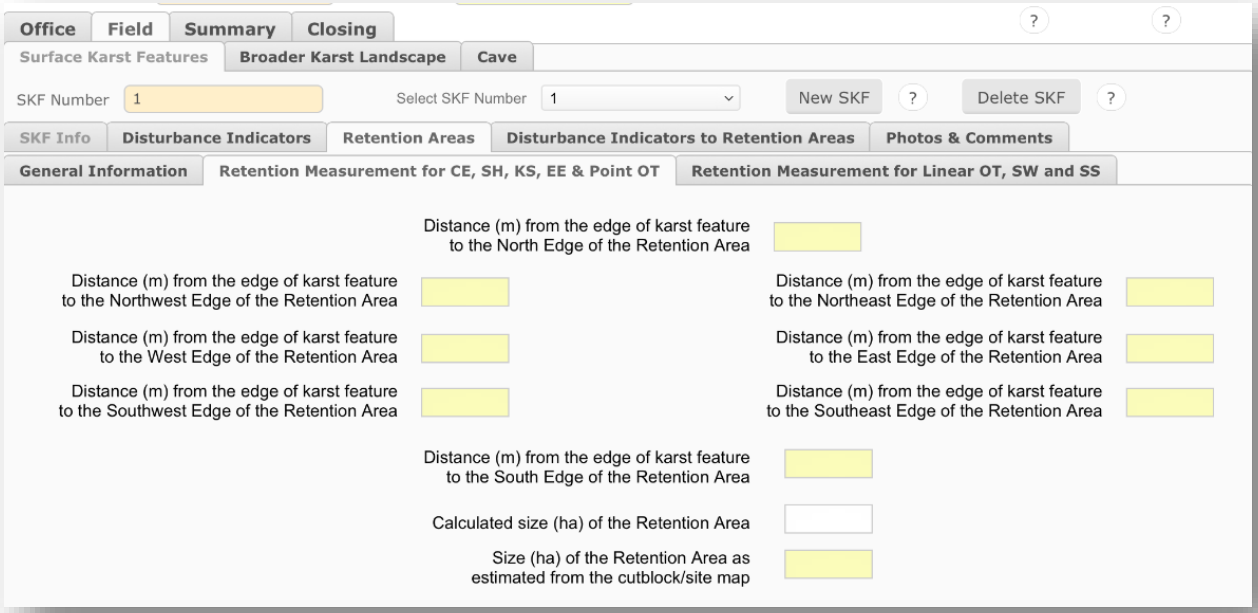


Figure 43: Measuring the Size of a Retention Area

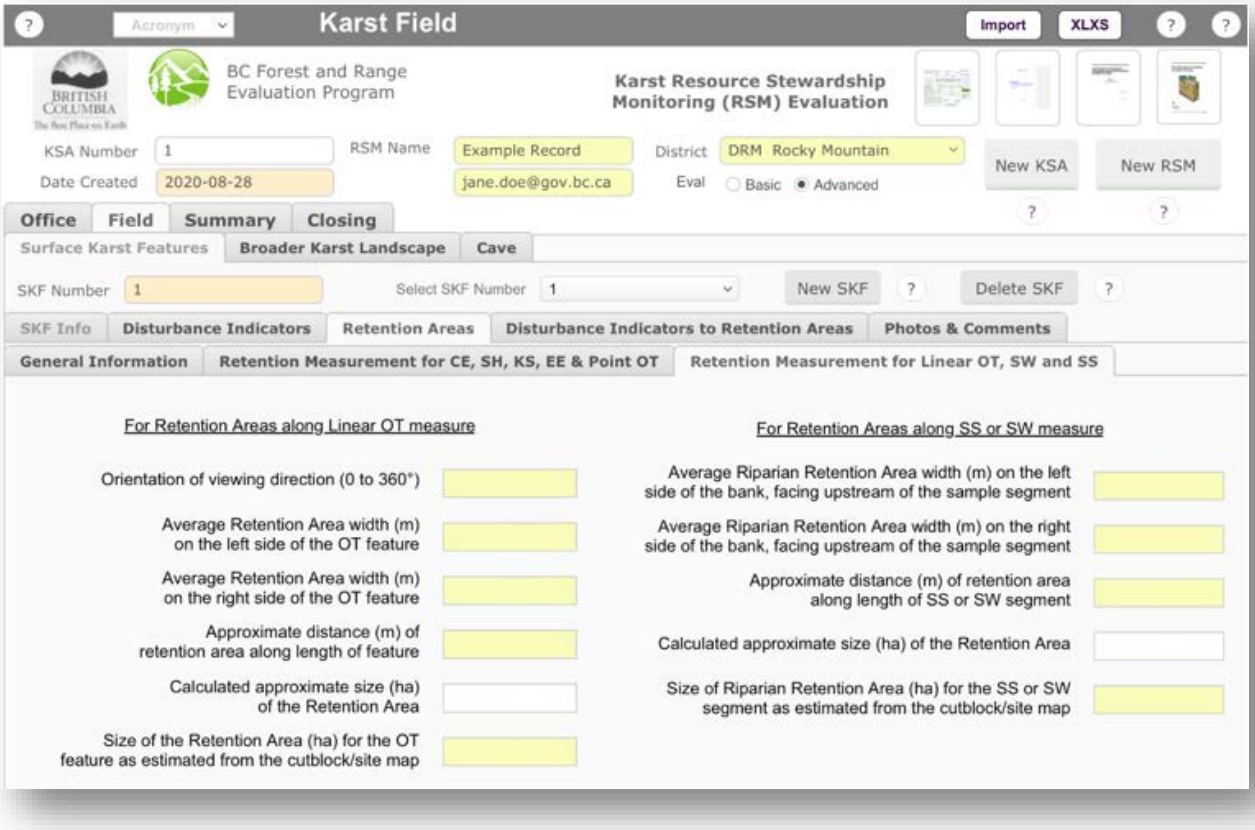


[14] It is good practice even for an experienced field person to confirm estimated distances occasionally with a measuring device.

[15] Field testing showed that measurements of just the four cardinal directions of a retention area could result in misleading calculated areas, so the intermediate directions were added.

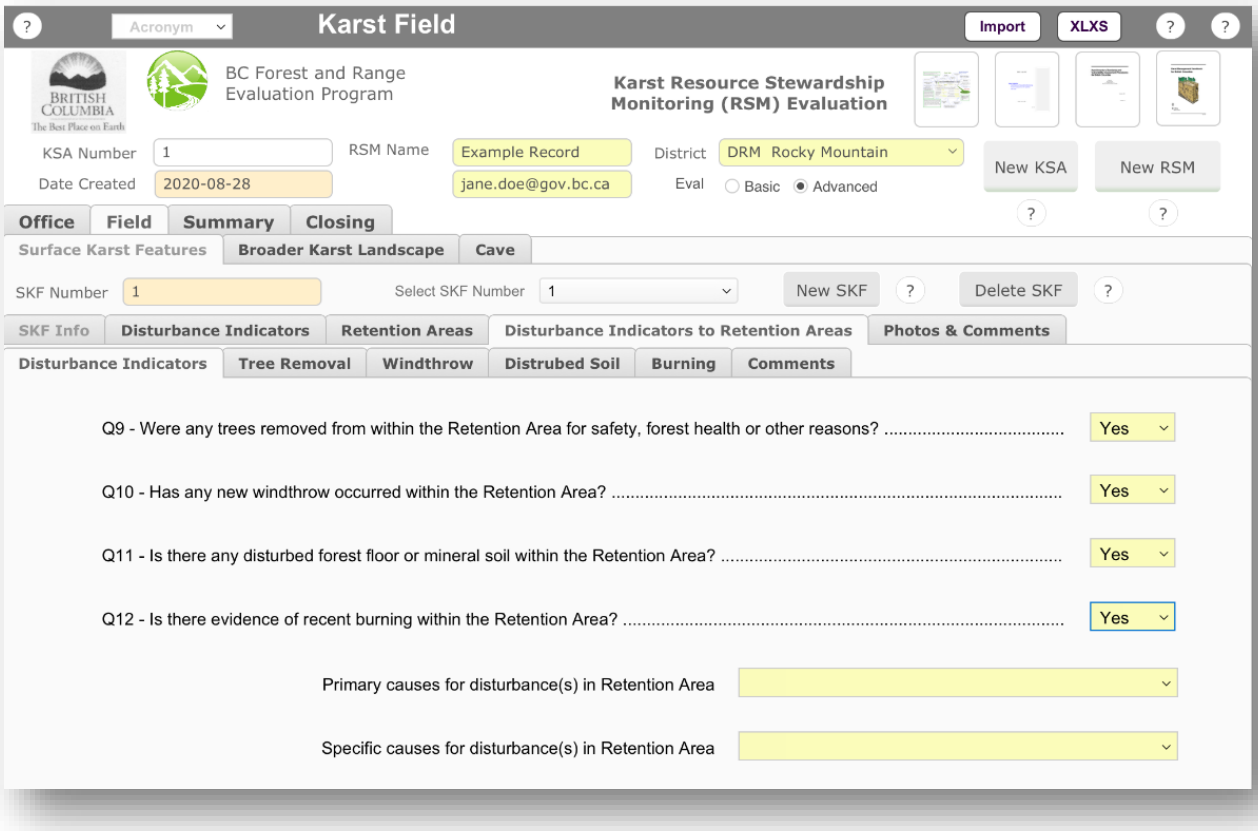
Retention Measurement for Linear OT, SW and SS

Refer to the ***Retention Measurement for Linear OT, SW and SS*** tab. For linear features, such as elongated OT features (e.g., limestone bluffs), SSs or SWs, the cardinal measurement system is not practical. In this case, the feature should be walked along its length beginning at one end and finishing at the other (or in the case of a SW or SS, the sampled section). The direction of travel or viewing direction should be measured using a compass, and the width of the retention area estimated to the left and right at several locations (e.g., every 15-20 m). These widths should then be averaged and recorded.



Disturbance Indicator Questions for Retention Areas Surrounding Surface Karst Features

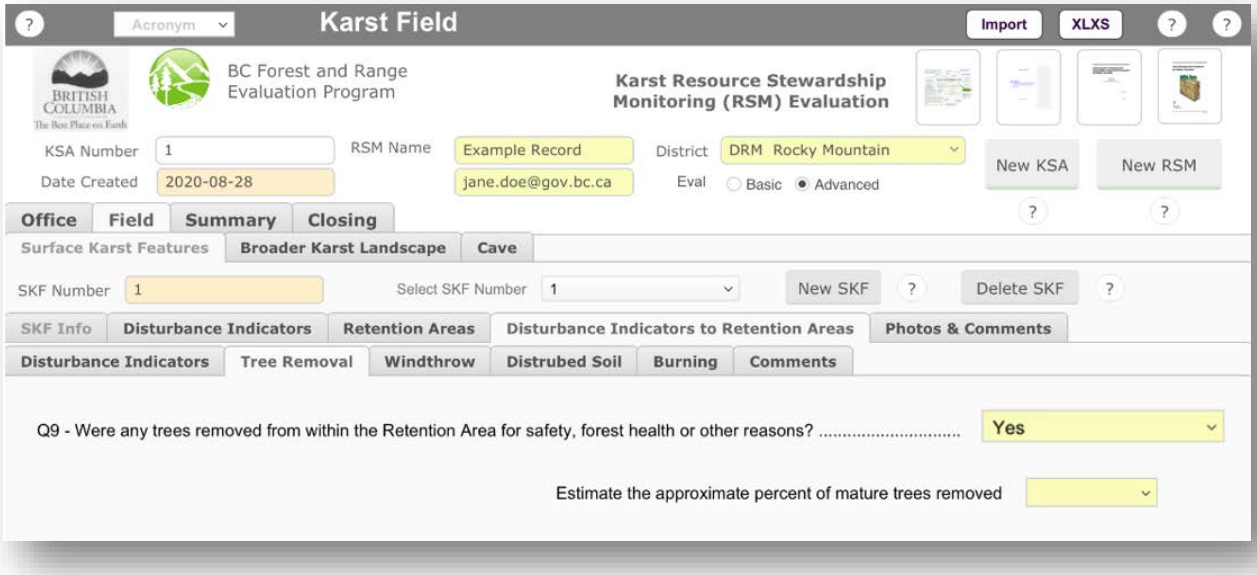
Refer to the ***Disturbance Indicators to Retention Areas*** tab. The examination of disturbances in retention areas that surround SKF is an Advanced Options of the FREP Karst Evaluation. The primary purpose of retention areas surrounding surface karst features is to provide protection for the karst resources. If disturbance occurs within the retention area, the level of protection for that karst feature could potentially be reduced. The types of disturbances that can occur in retention areas include: tree removal, windthrow, disturbed forest floor or mineral soil and burning. Any of these four disturbance types could potentially reduce the functionality of the retention area, and lower the protection given to the karst feature such as altering shade, introducing deleterious materials - hydrologically or otherwise to the subsurface. The ***Disturbance Indicators to Retention Areas/Disturbance Indicators*** tab outlines the four disturbance indicator questions for retention areas surround SKF.


Acronym
Karst Field
Import
XLXS
BC Forest and Range
Evaluation Program
Karst Resource Stewardship
Monitoring (RSM) Evaluation
KSA Number 1
Date Created 2020-08-28
RSM Name Example Record
jane.doe@gov.bc.ca
District DRM Rocky Mountain
Eval Basic Advanced
New KSA
New RSM
Office
Field
Summary
Closing
Surface Karst Features
Broader Karst Landscape
Cave
SKF Number 1
Select SKF Number 1
New SKF
Delete SKF
SKF Info
Disturbance Indicators
Retention Areas
Disturbance Indicators to Retention Areas
Photos & Comments
Disturbance Indicators
Tree Removal
Windthrow
Distrubed Soil
Burning
Comments
Q9 - Were any trees removed from within the Retention Area for safety, forest health or other reasons? ..... Yes
Q10 - Has any new windthrow occurred within the Retention Area? ..... Yes
Q11 - Is there any disturbed forest floor or mineral soil within the Retention Area? ..... Yes
Q12 - Is there evidence of recent burning within the Retention Area? ..... Yes
Primary causes for disturbance(s) in Retention Area
Specific causes for disturbance(s) in Retention Area

Tree Removal in Retention Area

Q9 - Were any trees removed from within the Retention Area for safety, forest health or other reasons? (Yes, No)

Refer to the ***Disturbance Indicators to Retention Areas/Tree Removal*** tab. The purpose of a retention area is to retain tree cover to provide protection for the karst feature. However, there may be circumstances where trees have been removed from the retention area (e.g., health, safety). These may be identified in the site plan. In this case, the number of trees removed should be estimated visually, and the causes determined.

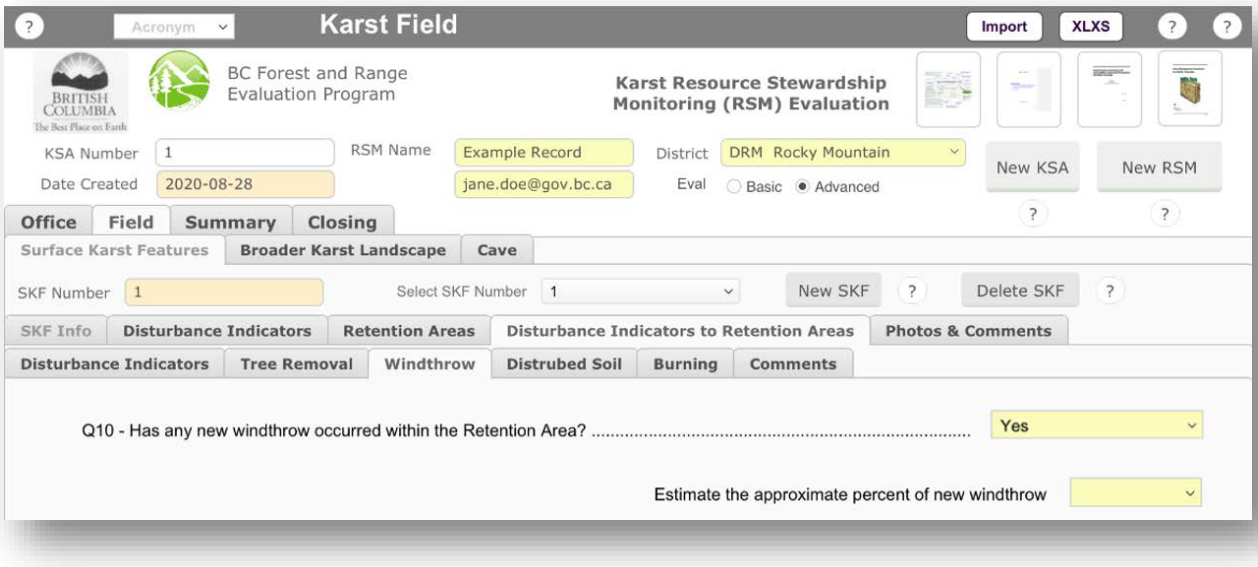


Windthrow in Retention Area

Q10 - Has any new windthrow occurred within the Retention Area? (Yes, No)

Refer to the ***Disturbance Indicators to Retention Areas/Windthrow*** tab. Windrow is likely to be one of the most common disturbances in a retention area surrounding karst features. For example, a study of retention areas surrounding karst features on Northern Vancouver Island indicated that up to 80% of retention areas suffered some level of windthrow (Stokes, 2016). However, it was found that even though windthrow had occurred in the retention areas, the total number of disturbances at the karst features appeared to be reduced in comparison to those features not surrounded by retention areas (Stokes, 2016).

Enter a visual estimate of the percent of new windthrow:

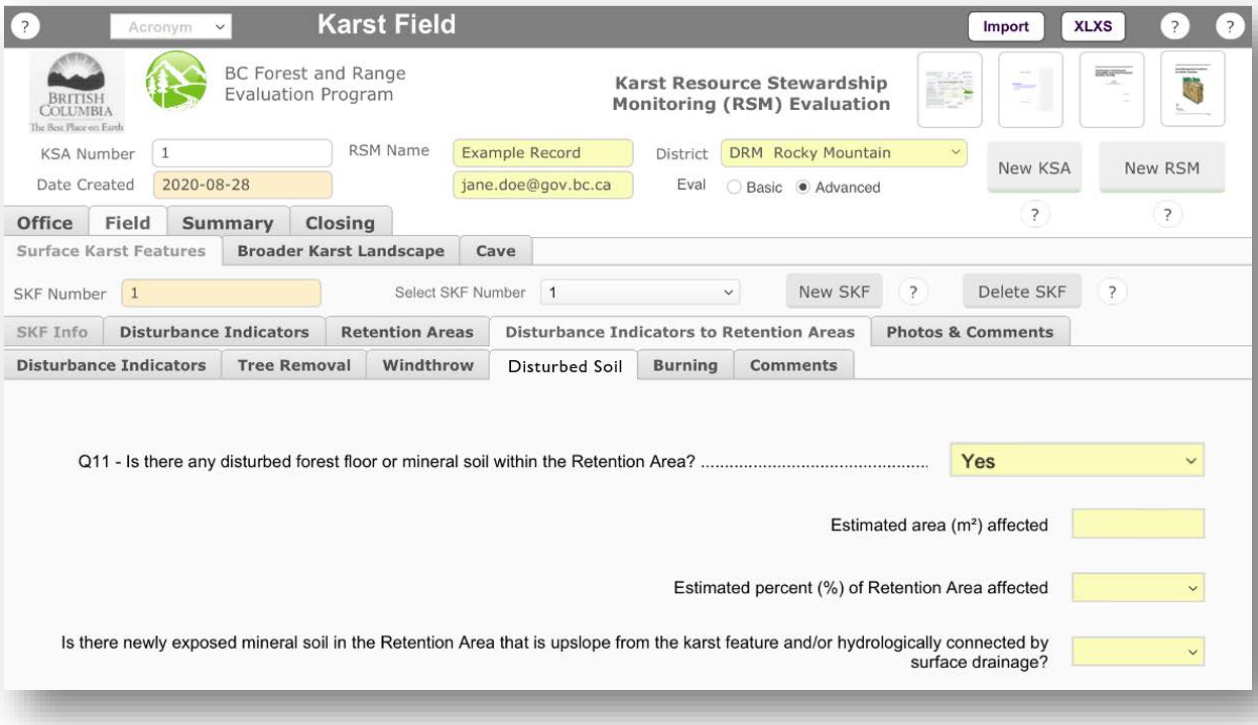


Disturbed Soil or Forest Floor in the Retention Area

Q11 - Is there recently disturbed forest floor or mineral soil within the Retention Area? (Yes, No)

Refer to the ***Disturbance Indicators to Retention Areas/Disturbed Soil*** tab. Disturbed soil or forest floor would not typically be anticipated in a retention area; however, it might occur due to a landslide or road failure extending into a retention area, or from windthrow. Machinery would not normally enter a retention area, but this could happen if partial retention or thinning occurred.

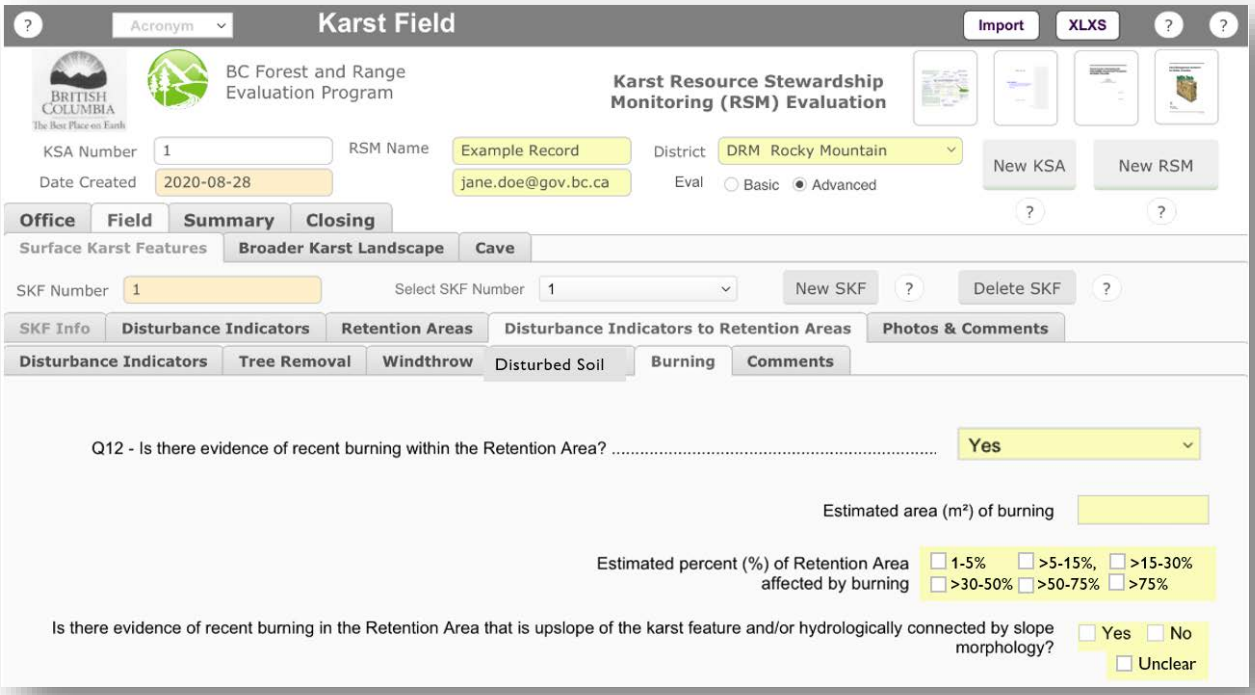
Enter in visual estimates of affected area. Hydrological connectivity is assumed if exposed mineral soil could be potentially eroded and transported down gradient towards the karst feature.



Q12 - Is there evidence of recent burning within the Retention Area? (Yes or No)

Refer to the ***Disturbance Indicators to Retention Areas/Burning*** tab. Burning within a retention area is unlikely to be planned, and more likely due to either man-made or natural fire events Burning could lead to the adverse effects to karst resources such as: soil loss, bedrock calcification, and infiltration of smoke, soot or ash into the subsurface.

Enter in visual estimates of affected area. Hydrological connectivity is assumed if fine materials could be potentially eroded and transported down gradient towards the karst feature.



6.2 *Field/Broader Karst Landscape –* Broader Karst Landscape Evaluation

Refer to the ***Field/Broader Karst Landscape*** tabs. Examination of the Broader Karst Landscape is one of the Advanced Options of the FREP Karst Evaluation and is only carried out in certain circumstances, as determined by the district FREP lead. Typically, the gathering of BKL information occurs at designated sample plots within harvested or forested areas. Part of the BKL data gathering procedure (***Field/Broader Karst Landscape/BKL info*** tabs) is to collect enough information so that a Surface Karst Sensitivity rating can be determined. Following this, data should then be collected (***Broader Karst Landscape/Disturbance Indicators*** tab) on disturbances within the sample plot related to: tree removal, windthrow, disturbed soil/forest floor/bedrock, introduced materials (into small-scale karst openings) and burning. Previous disturbances are also considered for the sample plot.

The location of the BKL sample plots can be predetermined prior to field work and situated such that they occur between SKF sample sites. The BKL sample plot should be in either a harvested area or a forested area. It should not straddle both. Roads should not be included. The size of the BKL sample plot is typically 0.25 ha, with a marked central point and a radius of 28.2 m. The plots size can be

increased to 0.5 ha or 1 ha (radii of 39.9 m and 56.4 m respectively), if time is available and access/walking across sample plot is reasonable.

Firstly, the central point of the sample point is flagged. The sample plot can be examined by a combination of visual observations from the centre point and by walking around the plot. A 'Figure 8' search route is one way to cover the BKL sample plot (see Figure 44)[16]. An assistant can also help by measuring out the cardinal points of the plot. As the assessor walks the sample plot it should be possible to visually assess information on: average soil thickness, level of epikarst development, number of negative SKFs and karst roughness. A series of visual charts Figures 33, 45 and 46 are available to assist with this. At the same time information related to disturbance indicators can also be collected.

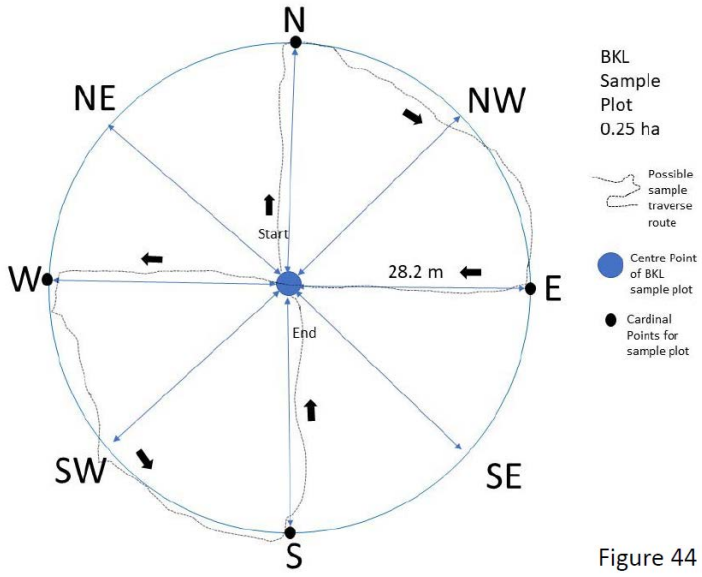


Figure 44

Figure 44: Figure '8' Search Route for Examining BKL Sample Plots

[16] Typically, a 0.25 ha sample plot can be made by walking northward for 28.2 m to the north cardinal point, then to the southeast to east cardinal plot, from here westward for 56.4 m through the centre point to the west cardinal point, from here to the southeast to the south cardinal point, and finally northward 28.2 m to the centre point.

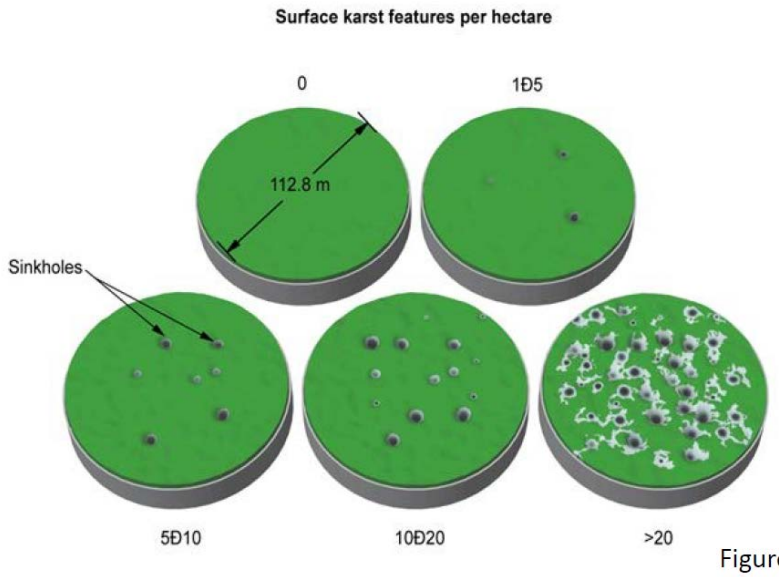


Figure 45

Figure 45: Visual Chart for Estimating Surface Karst Feature Density

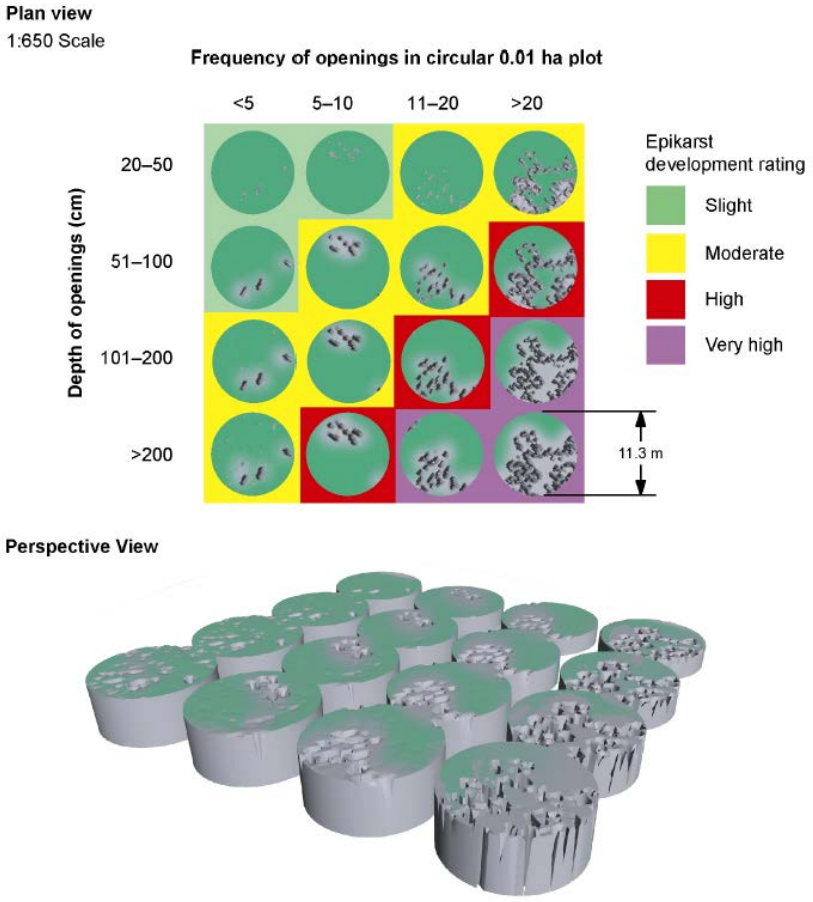
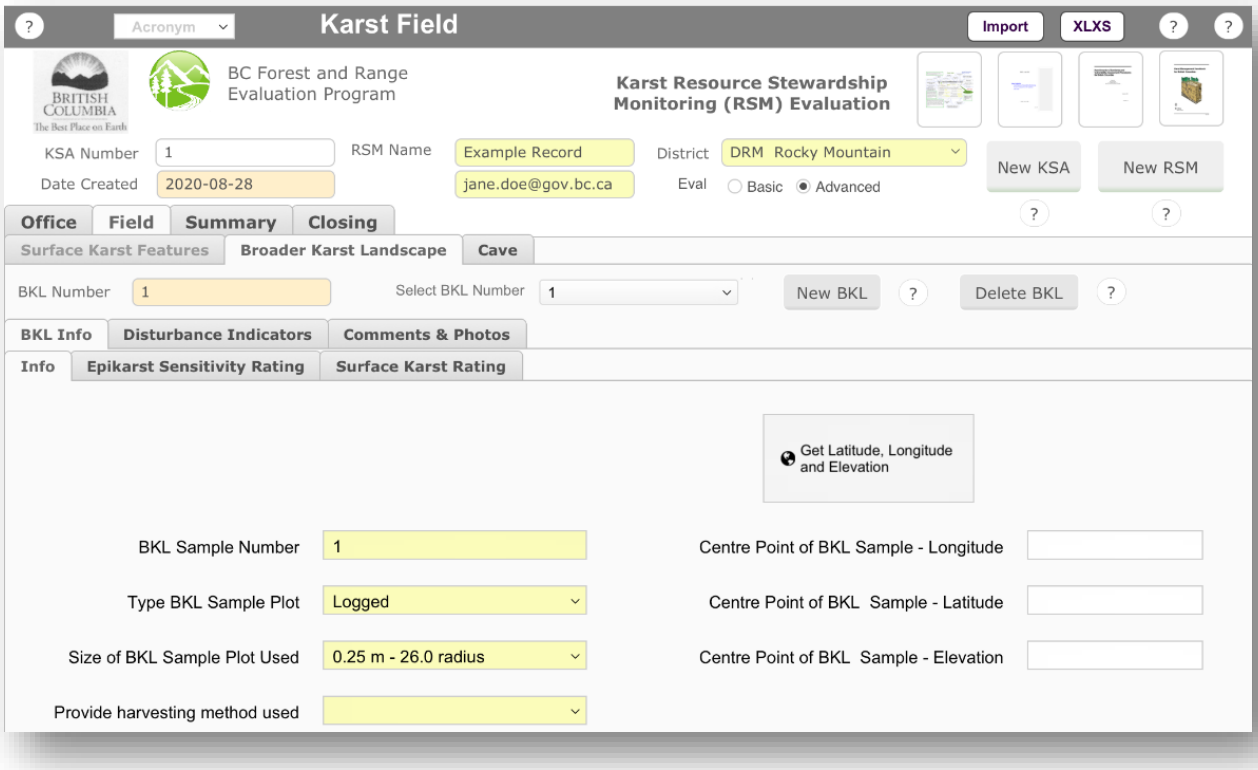


Figure 46: Visual Chart for Rating Epikarst Development

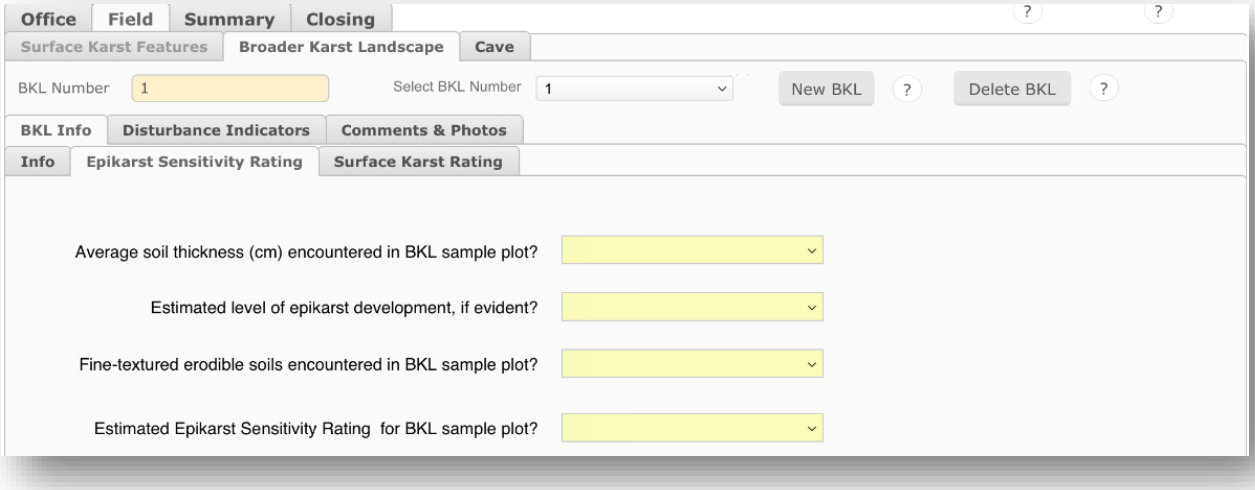
General Information on the Broader Karst Landscape (BKL) Sample Plot

General information on the type, size and location of the BKL sample plot is collected onto the ***Broader Karst Landscape/BKL Info/Info*** tab as follows:



Epikarst Sensitivity Rating

The ***Broader Karst Landscape/BKL Info/Epikarst Sensitivity Rating*** tab, the second page of this section, collects data related to epikarst sensitivity in the BKL sample plot - soil thickness, epikarst development, and fine-textured soils.



- Average soil thickness (cm) encountered in BKL sample plot (>200, 101-200, 51-100, 20-50, <20, Bedrock). - This information requires some level of judgement and depends on the amount of exposed bedrock present and the overall site conditions. Soil thickness can be determined from natural exposures, windthrow or hand pits. A heavy gauge (5 mm) steel rod with marked (0.1 m) intervals is useful for probing soil to bedrock. Forest floor in this sampling is considered part of the soil. Examination of nearby road cuts is also useful. Soil thickness measurements need to be averaged and extrapolated over the sample plot.
- Estimated level of epikarst development, if evident (Slight, Moderate, High, Very High) - Most areas of karst have some evidence for surface epikarst development, some may be visible on the surface at epikarst exposures or beneath windthrow. Details on how to determine epikarst development are outlined in KISVAP (p.47) using the frequency and average depth of solutional openings. A 10 m by 10 m calibration plot can be used to assist in this measurement. In many cases, what is seen at one or more sites needs to be averaged and extrapolated for the sample plot. Figure 46 provides a visual chart for determining epikarst development.
- Fine-textured erodible soils encountered in BKL sample plot (Yes, No) - Fine-textured soils are considered loose to compact silt and sand with <20% coarse fragments. Soil texture can be determined from natural exposures, windthrow or hand pits.
- Estimated Epikarst Sensitivity Rating for BKL sample plot (Low, Moderate, High, Very High) - This can be determined using the estimates for soil thickness and epikarst development using the appropriate table from the 4-Step Karst Vulnerably Assessment Procedure (Figure 47). If fine-textured soils are present this raises the Epikarst Sensitivity Rating by one category.

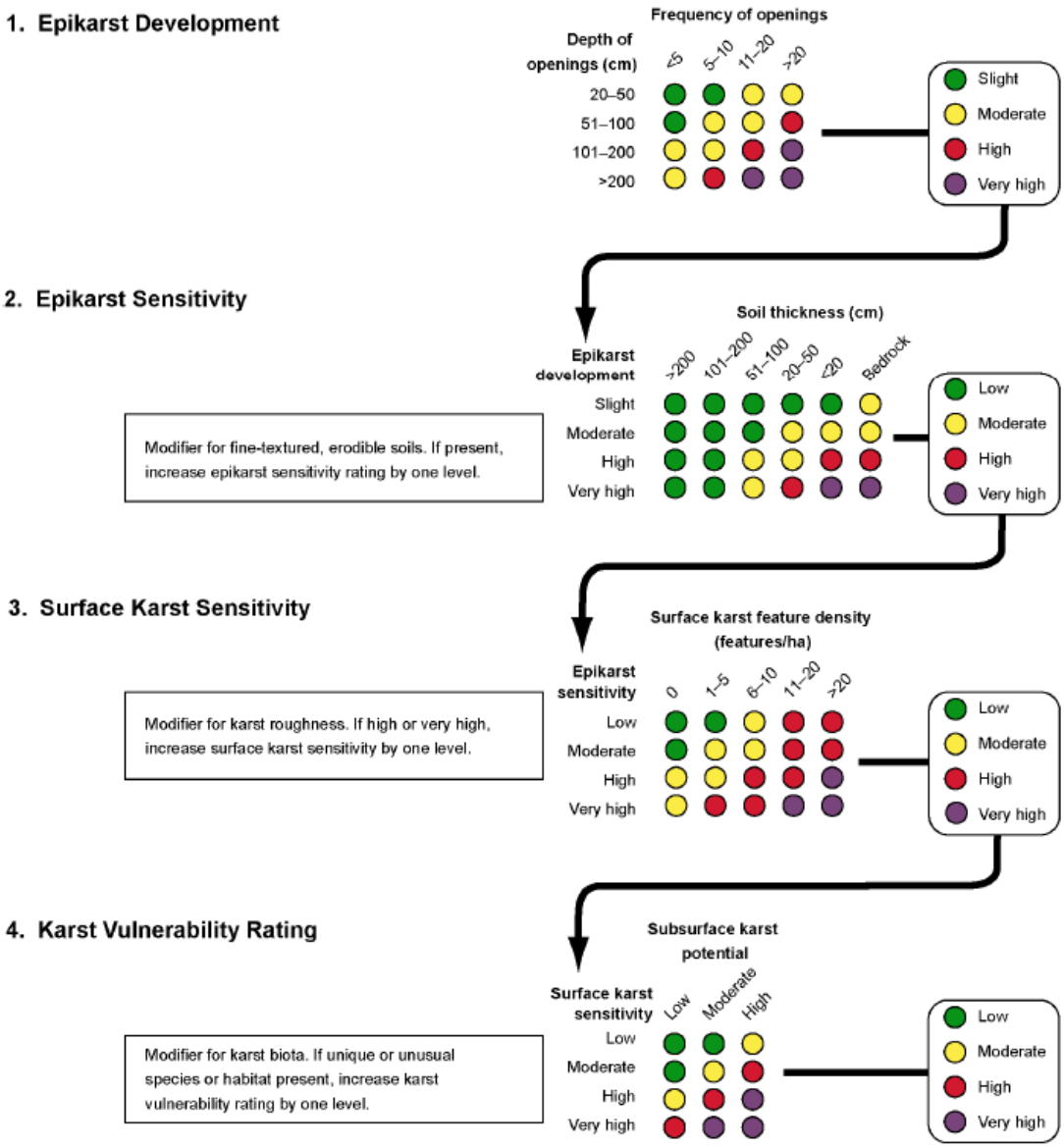
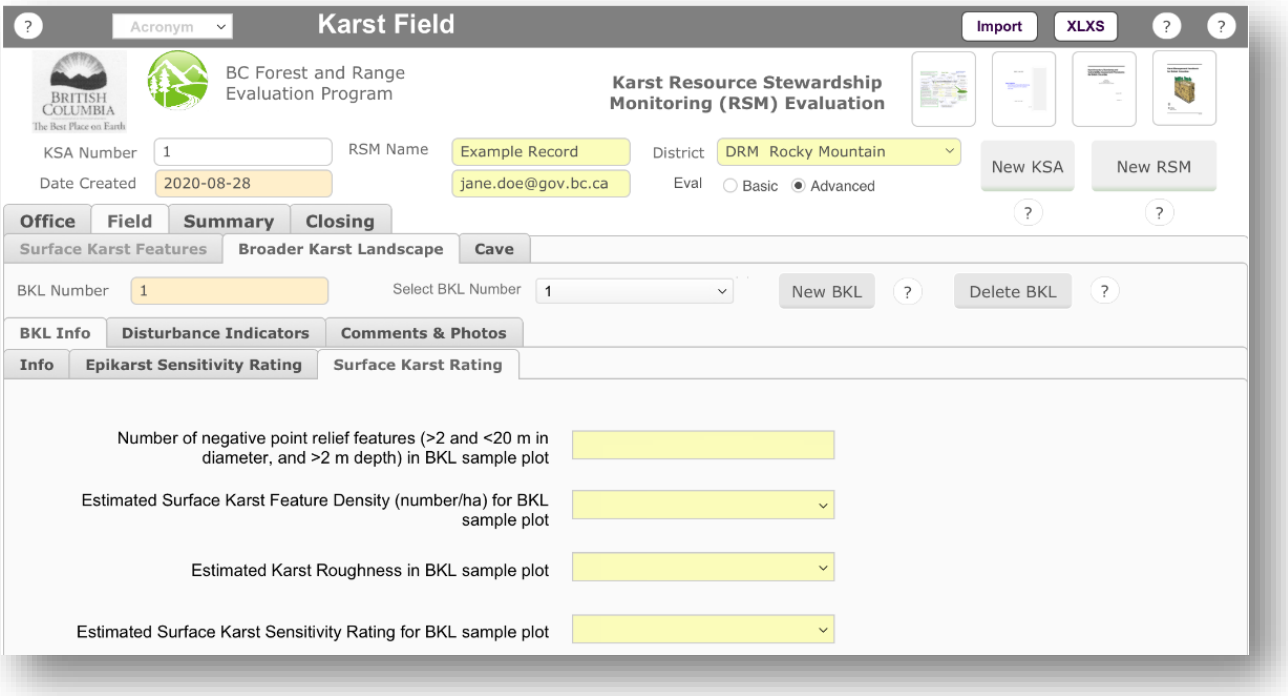


Figure 47. Karst Vulnerability Assessment Procedure (from KISVAP, page 67)

Surface Karst Sensitivity Rating

The third part of this section on the ***Broader Karst Landscape/BKL Info/Surface Karst Rating*** tab uses the findings from the ***Epikarst Sensitivity Rating*** tab and combines this with surface karst feature density and karst roughness data to obtain a Surface Karst Sensitivity rating.



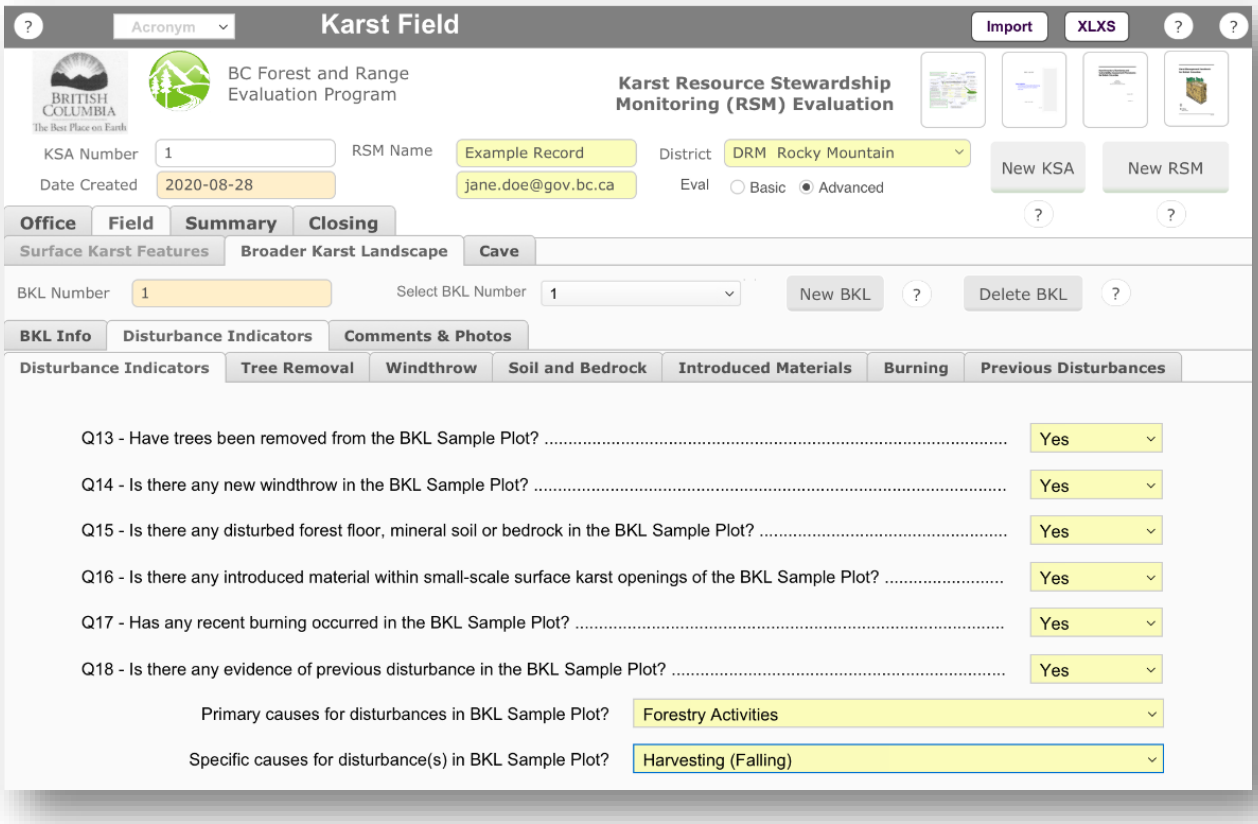
- Number of negative point relief features (>2 and <20 m in diameter, and >2 m depth) in BKL sample plot - In this case the actual number of features should be recorded. The site plan or KFA map may assist in this. Features found straddling the boundary of the plot should be included.
- Estimated Surface Karst Feature Density (number/ha) for BKL sample plot: (0, 1-5, 6-10, 11-20, >20): The visual chart in Figure 45 can also be used to estimate surface karst feature density.
- Estimated Karst Roughness in BKL sample plot: (Low, Moderate, High, Very High). Roughness is an evaluation of the irregularity or overall unevenness of the karst terrain and considers the proportion of negative versus positive relief features. This is best estimated using Figure 32, a visual chart for karst roughness.
- Estimated Surface Karst Sensitivity Rating for BKL sample plot (Low, Moderate, High, Very High, Unclear) - This can be determined using the Epikarst Sensitivity rating from Page 33 combined with the surface karst feature density using the appropriate table from the 4-Step Karst Vulnerably Assessment Procedure (Figure 47). If a high or very high karst roughness values is present at the site, the Epikarst Sensitivity Rating is raised by one category.

The estimated Surface Karst Sensitivity Rating obtained for BKL sample plot is a step towards determining the overall karst vulnerability of a site, which would also include an estimate of subsurface

karst potential. Obtaining an estimate of surface karst sensitivity is likely at the limit of the assessor's time and expertise for site but is an important measurement for the BKL[17].

Disturbance Indicator Questions for BKL Sample Plots

During collection of the basic data for the BKL sample plot, information should also be collected for the type and nature of recent disturbances. In a logged/harvested sample plots tree removal, disturbed soil/forest floor/bedrock, introduced materials (into small-scale karst openings) and burning are the most likely types of disturbances that could be encountered. In forested sample plots, windthrow or a natural event such as a slide is likely the only type of disturbance. For each of the disturbance questions (Q13-Q18) on the ***Field/Broader Karst Landscape/Disturbance Indicators*** tab, a Yes/No response is required.

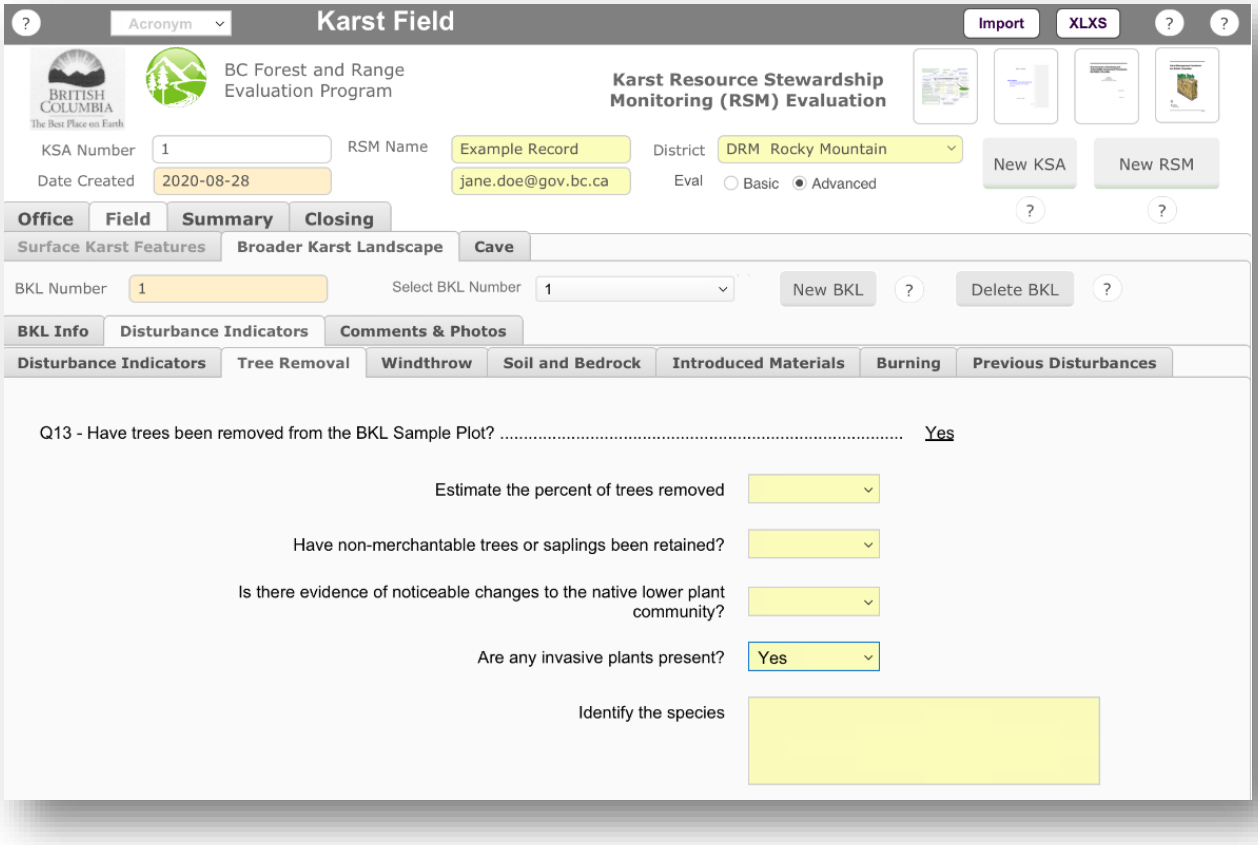


[17] Note the SKS rating obtained for a BKL sample plot should only be extrapolated with care (i.e., if other BKL sample plots are done in nearby areas). The SKS ratings obtained in a KFA are linked to karst polygons that are typically 1-10 ha in size.

Tree Removal and BKL

Q13 - Have trees been removed from the BKL Sample Plot? (Yes, No)

Tree removal of varying amounts (up to 100%) is likely to occur in harvested BKL sample plots, while tree removal is likely be limited to none (0%) in forested BKL sample plots. Refer to the ***Broader Karst Landscape/Disturbance Indicators/Tree Removal*** tab.

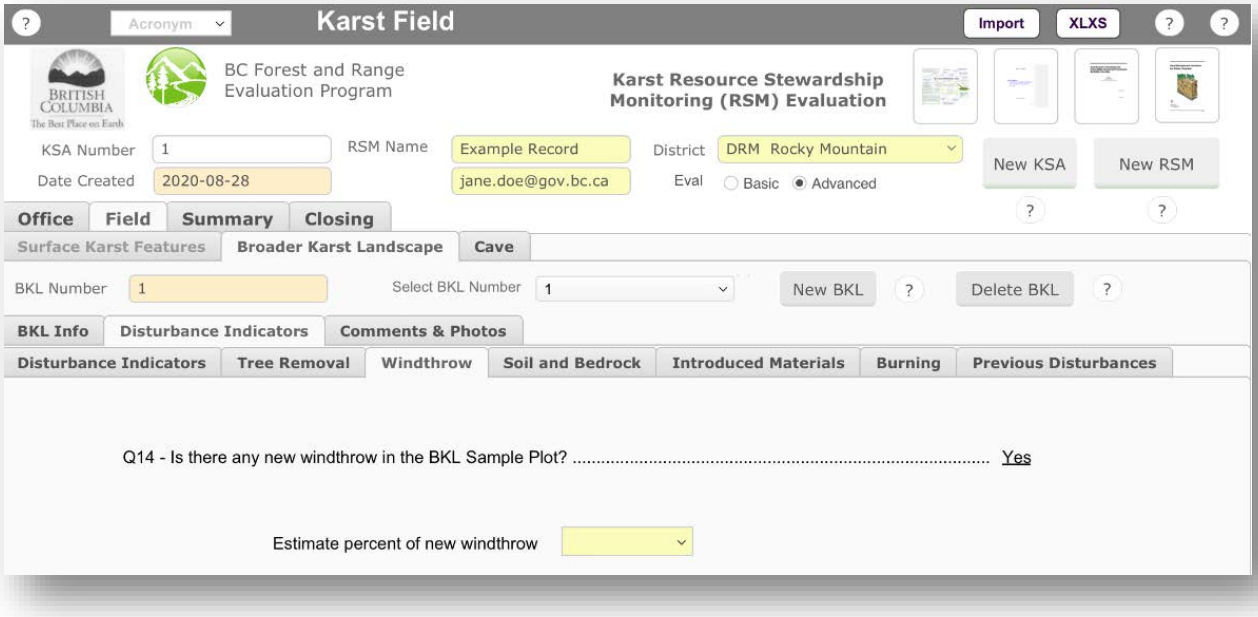


Windthrow and BKL

Q14 - Is there any new windthrow in the BKL Sample Plot (Yes, No)

Windthrow is most likely to occur within forested BKL sample plots, particularly where they are located along the edges of harvested cutblocks. Enter a visual estimate of the percent of new windthrow.

Refer to the ***Broader Karst Landscape/Disturbance Indicators/Windthrow*** tab.

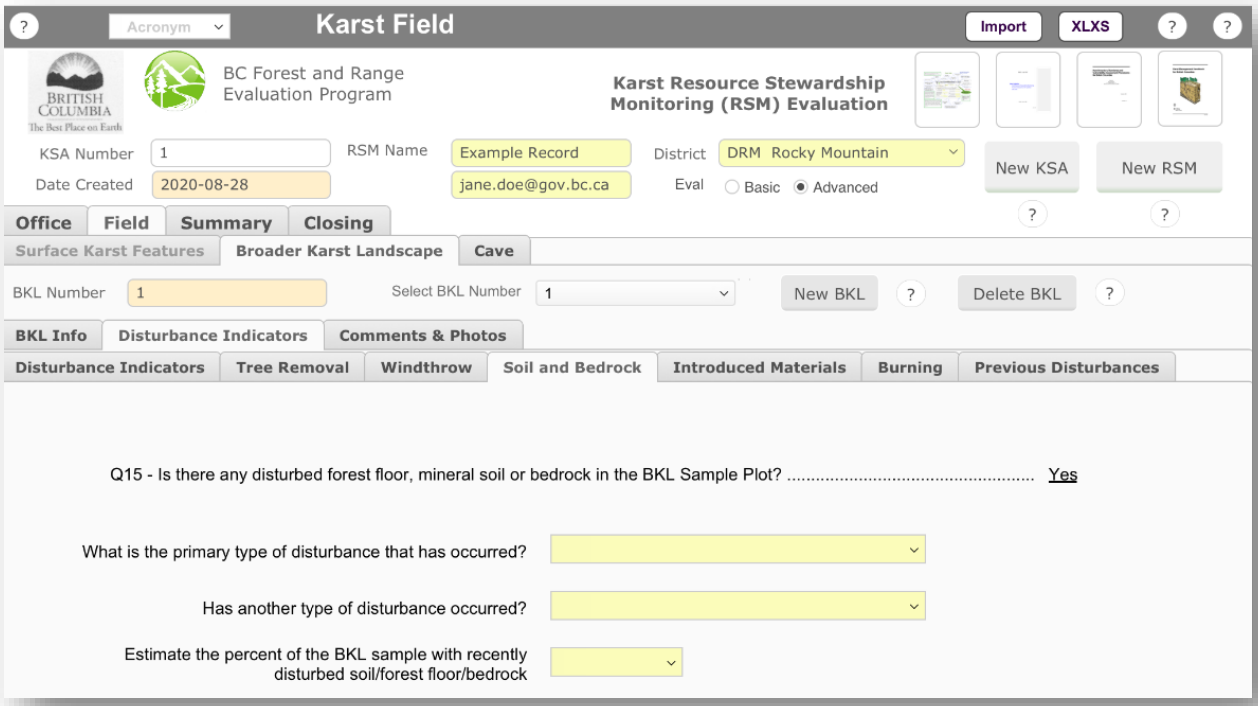


Disturbed Forest Floor, Mineral Soil and Bedrock in the BKL

Q15 - Is there any disturbed forest floor, mineral soil or bedrock in the BKL Sample Plot?

Disturbance to forest floor can occur when the forest floor is compacted or rutted during harvesting activities (e.g., along skid trails), without exposing mineral soil. Disturbed mineral soil is where the vegetative cover has been removed and weathered or unweathered soil has been exposed and/or moved. This soil material is susceptible to erosion and/or transport into karst features, affecting their hydrological and ecological functions, and potentially transporting sediment and other material into the subsurface. Disturbances can also expose karst bedrock surfaces or can result in physically broken karst bedrock (e.g., by ground-based machinery or cable-yarding). This can often occur on irregular and steep karst surfaces where bedrock highs or ridges are present.

Refer to the ***Broader Karst Landscape/Disturbance Indicators/Soil and Bedrock*** tab.



Introduced Materials and the BKL

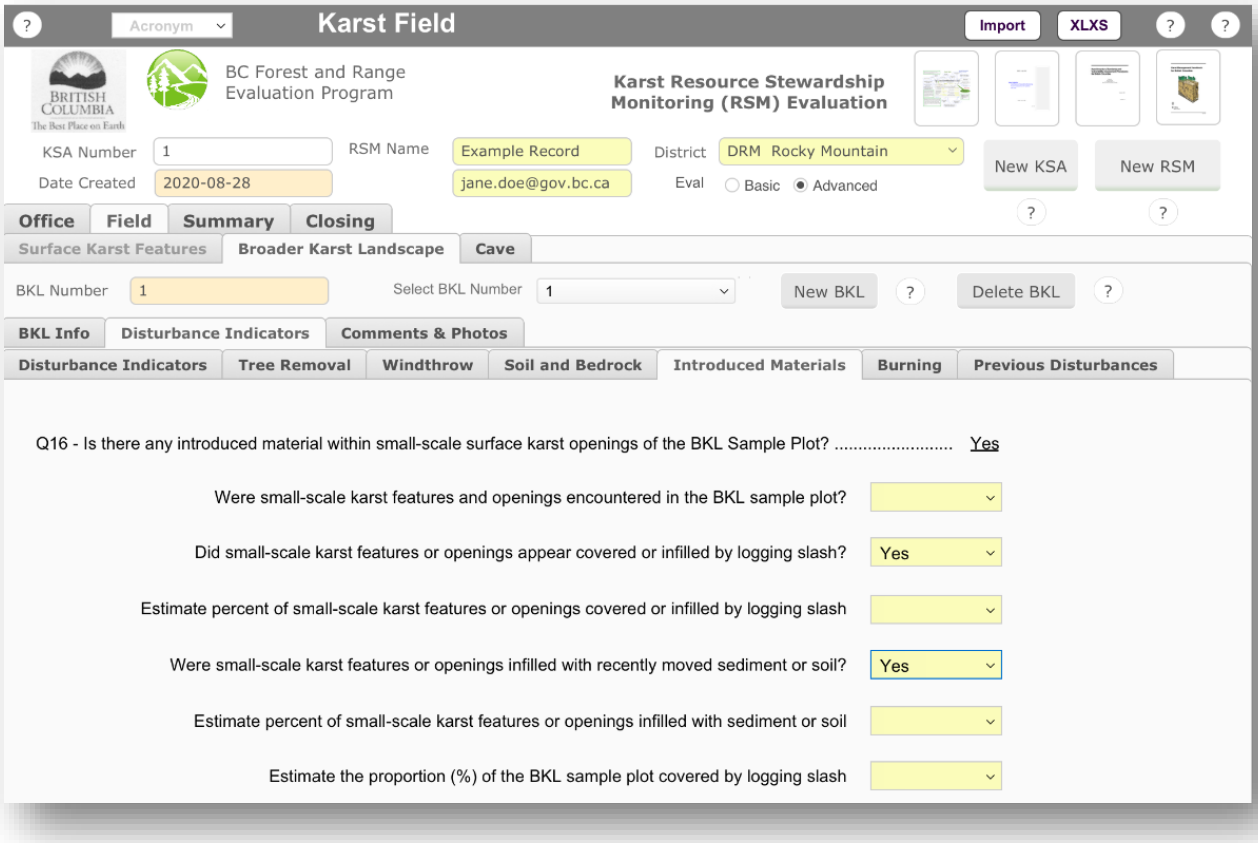
Q16 - Is there any recently introduced material in the small-scale surface karst openings of the BKL Sample Plot? (Yes, No)

Introduced materials into small-scale karst openings, particularly fine woody debris and fine sediment can lead to negative impacts for the subsurface. In this case, a qualitative evaluation is done to determine the percent of small-scale openings (e.g., vertical solution holes in epikarst) which were infilled with logging slash or sediment. Small karst features such as sinkholes would not be included unless openings present at the base. Features like grikes would be included. The goal is to estimate how much material has the potential to enter the epikarst. This can be estimated during walking the BKL

sample plot but could be problematic in areas covered by extensive logging slash. However, some extrapolation is possible.

For the question, “Were small-scale karst features or openings infilled with recently moved sediment or soil? (Yes, No, Unclear), sediment in this case can include fine inorganic materials or coarser material, such as road fill or fly rock.

Refer to the ***Broader Karst Landscape/Disturbance Indicators/Introduced Materials*** tab.

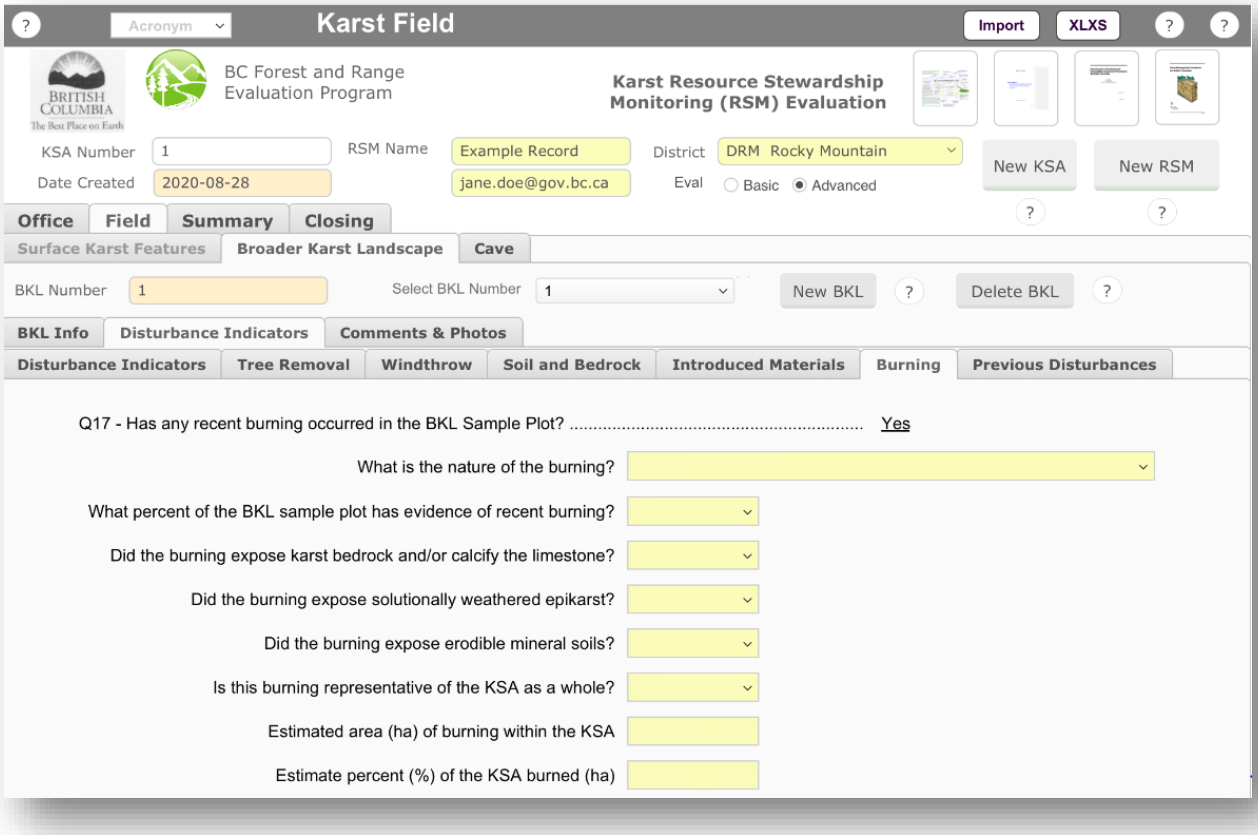


Burning and the BKL

Q17 - Has recent burning occurred on the BKL Sample Plot? (Yes, No)

Burning on the BKL, particularly in karst areas of greater sensitivity, can impact many attributes of the karst system, such as calcination and breakdown of limestone bedrock, carbonization of soils, and the formation of ash. These materials can be transported into surface openings and then into the subsurface. Flora and fauna can also be impacted. This question also tries to assess the extent of burning in the KSA, the intensity of the burn, and its impact (the last three sub-questions).

Refer to the ***Broader Karst Landscape/Disturbance Indicators/Burning*** tab.

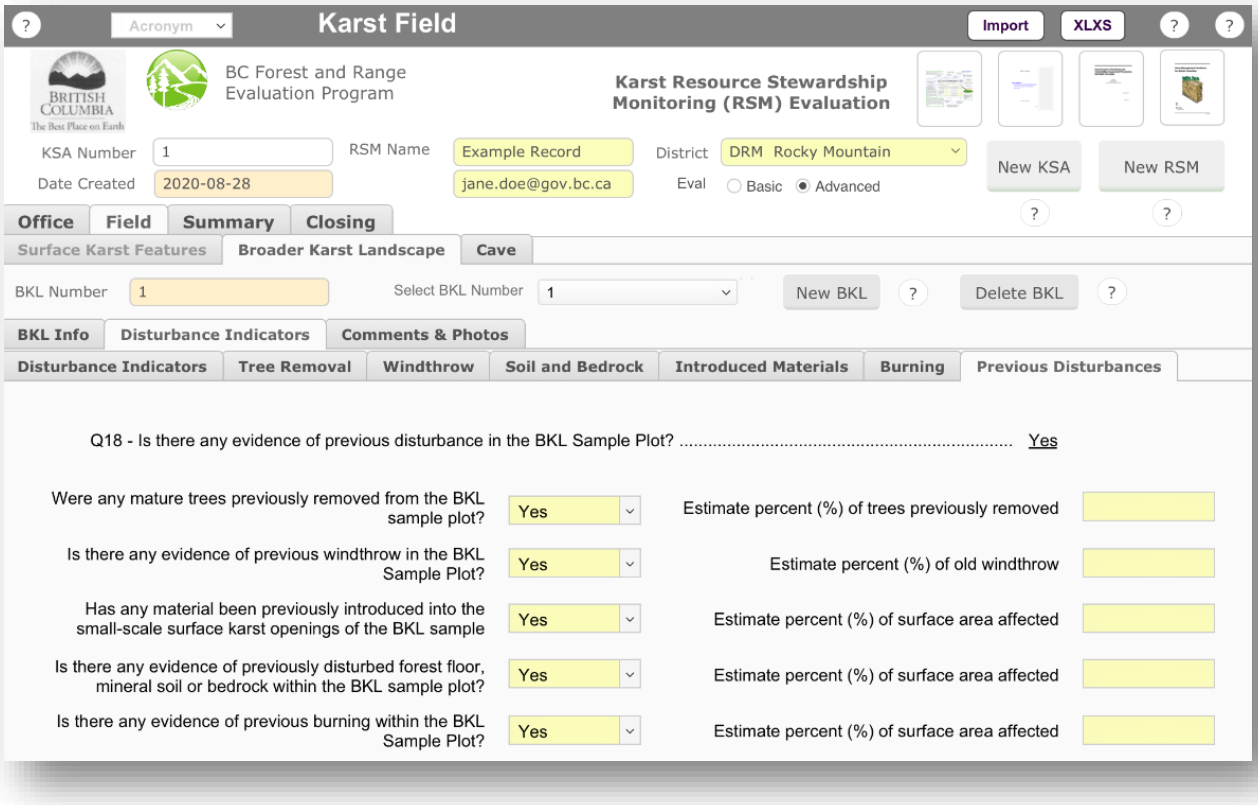


Previous Disturbances in the BKL

Q18 - Is there any evidence of previous disturbance(s) to the BKL Sample Plot? (Yes, No)

Previous disturbances may have occurred on in the BKL sample plot due to natural disturbances or past harvesting practices. These previous disturbances could have a cumulative effect on the overall function of the BKL sample plot and karst system. Examples of previous disturbances on the BKL that can be readily determined include: past tree removal, old windfall and burning. Estimates for the magnitude of these previous disturbances can be made if time available, but is likely more difficult for: introduced materials, disturbed soil/forest floor and disturbed bedrock.

Refer to the ***Broader Karst Landscape/Disturbance Indicators/Burning*** tab.



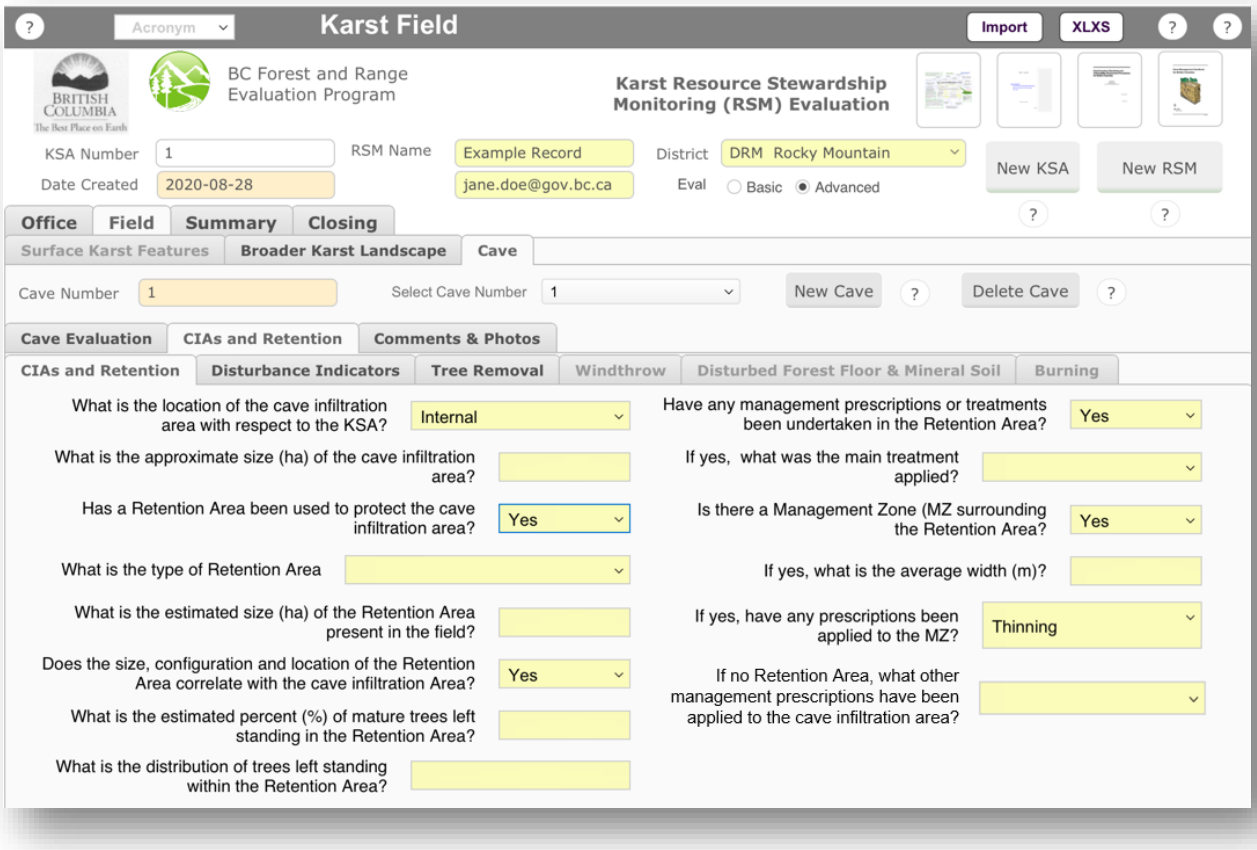
6.3 *Field/Cave* – Cave Infiltration Area Evaluations

The evaluation of Cave Infiltration Areas (CIAs) is one of the Advanced Options of the FREP Karst Evaluation and is only completed if a CIA has been delineated for a cave. The goal of the CIA Evaluation procedure is to confirm the location and extent of the CIA (e.g., the presence/absence of forest cover for a designated retention area) as well the potential disturbances to the CIA such as tree removal, windthrow, soil disturbance and burning.

Generally, if a CIA has not been determined during a KFA it is not possible to assess the conditions of the CIA above a cave during a FREP Karst Evaluation. However, with experience and if time available, it may be possible to delineate the CIA for a cave that has been mapped using the procedure outlined in Appendix 5.

General Information on Cave Infiltration Areas (CIAs) and Retention Areas

The ***Cave/CIAs and Retention*** tab assesses the extent and condition of the cave infiltration area and determines if tree cover and/or vegetation has been left intact, and whether a retention area has been used. Removal of tree cover is likely the greatest disturbance that might occur in the cave infiltration area, but other factors such as soil disturbance and burning may also be important.

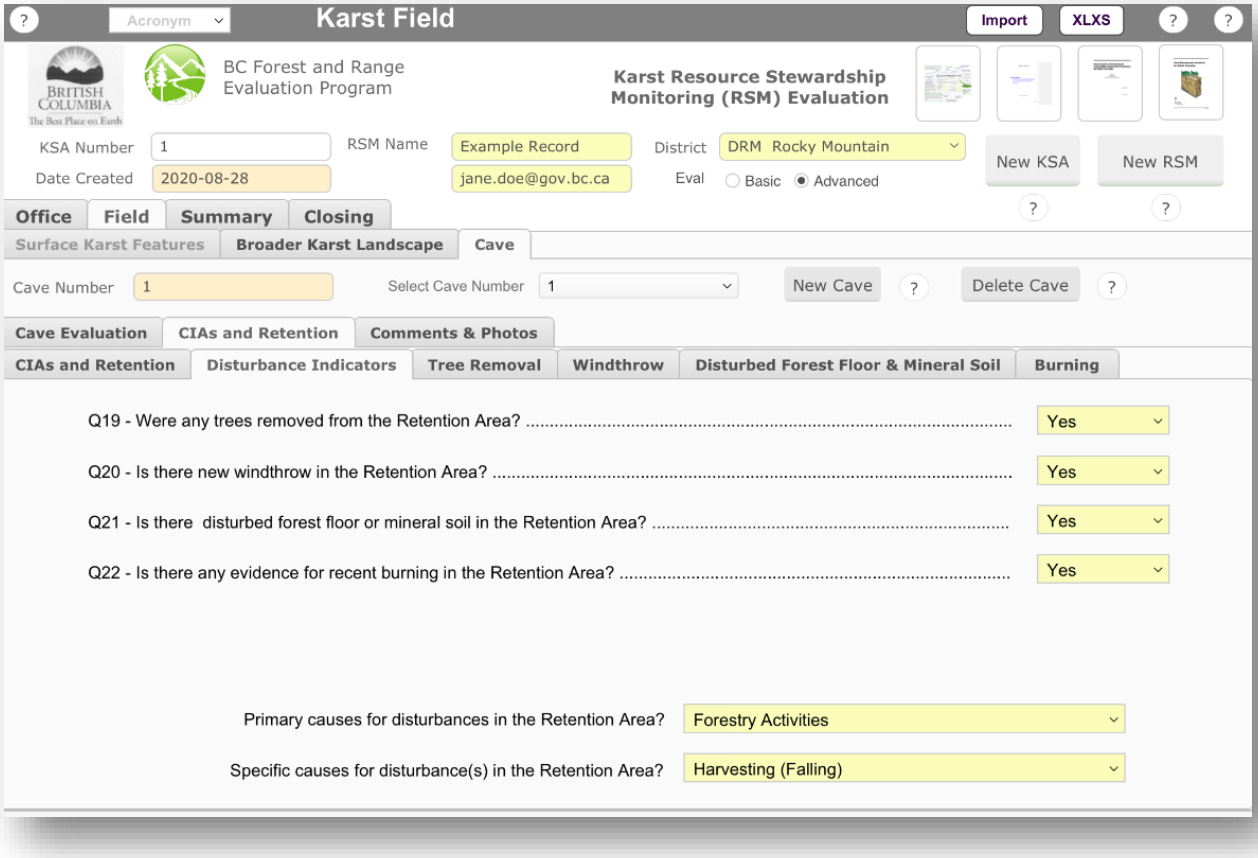


Whether the Retention Area correlates with the cave infiltration area is a subjective estimate to determine the relationship between the retention area examined in the field and the identified CIA on the site map.

Disturbance Indicator Questions for CIAs with Retention Areas

Disturbances in the CIA can be examined whether full retention is present or not. Typically, the CIA has fully intact tree cover if a reserve has been left, or alternatively it may have undergone some form of partial harvesting or other management prescription. The four disturbances types that are assessed include: tree removal, windthrow, disturbed forest floor/mineral soil and burning. Any of these four disturbance types could potentially reduce the functionality of the cave infiltration area by altering soil conditions, changing hydrology potentially impacting subsurface water quality, and impacting the cave climate and underground fauna.

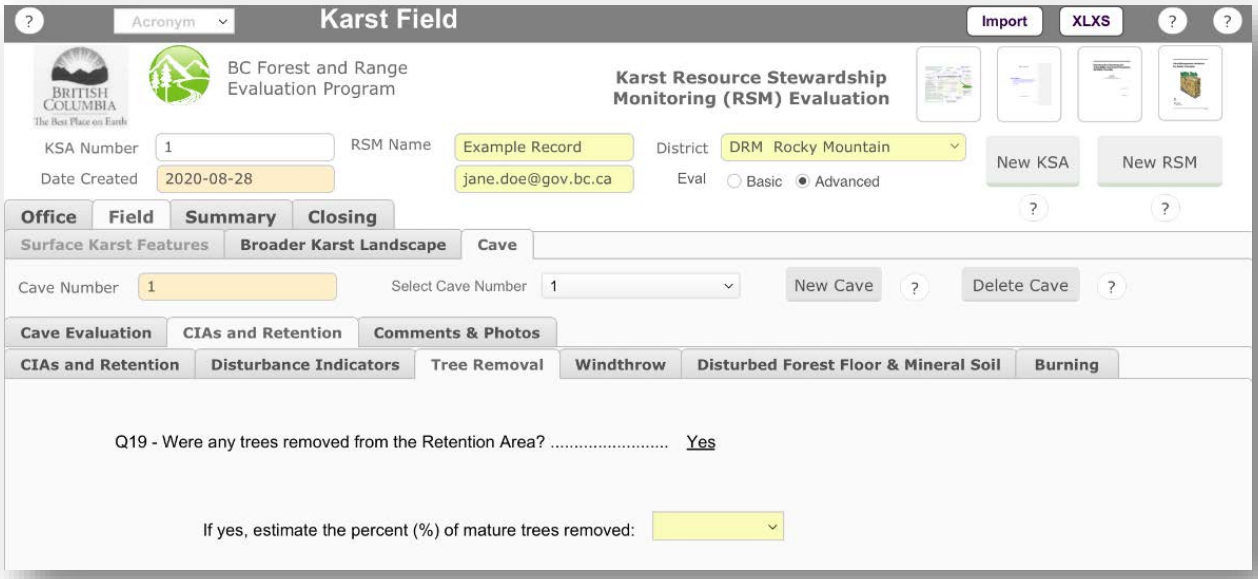
Refer to the ***Cave/CIAs and Retention/Disturbance Indicators*** tab.



Tree Removal in Retention Area above CIA

Q19 - Were any trees removed from the Retention Area? (Yes, No)

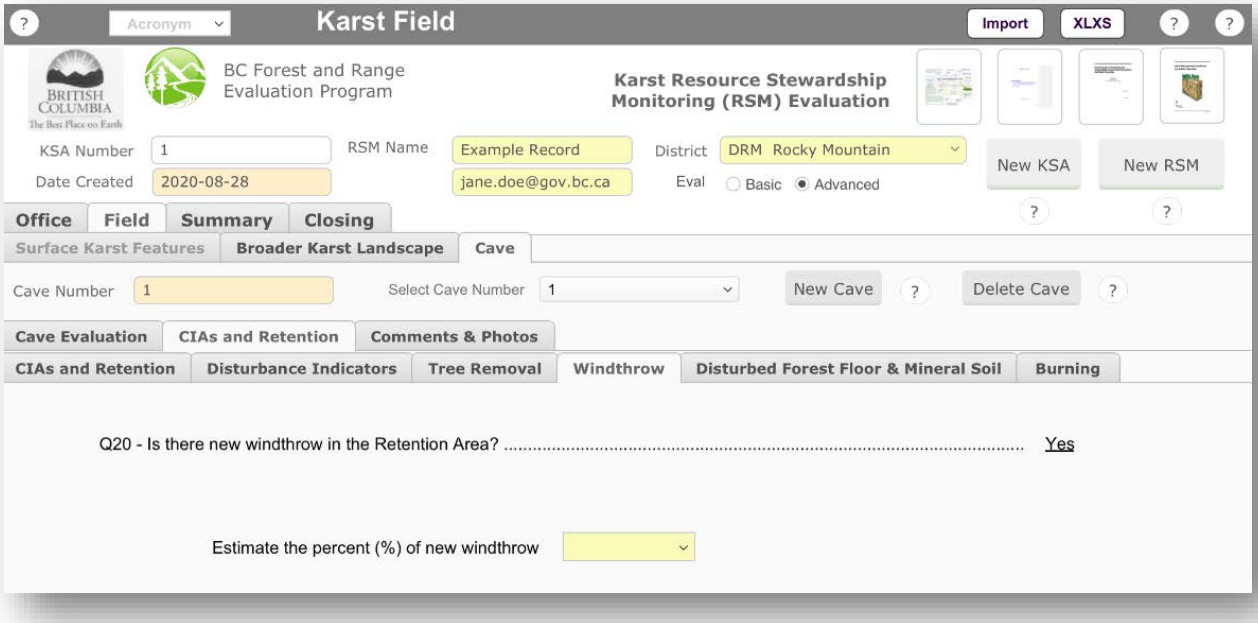
In many cases a retention area will cover the CIA, but it is possible that some or none of the CIA is covered by a retention area, and that the tree cover has been removed. Refer to the ***Cave/CIAs and Retention/Tree Removal*** tab.



Windthrow in Retention Area above CIA

Q20 - Is there new windthrow in the Retention Area? (Yes, No)

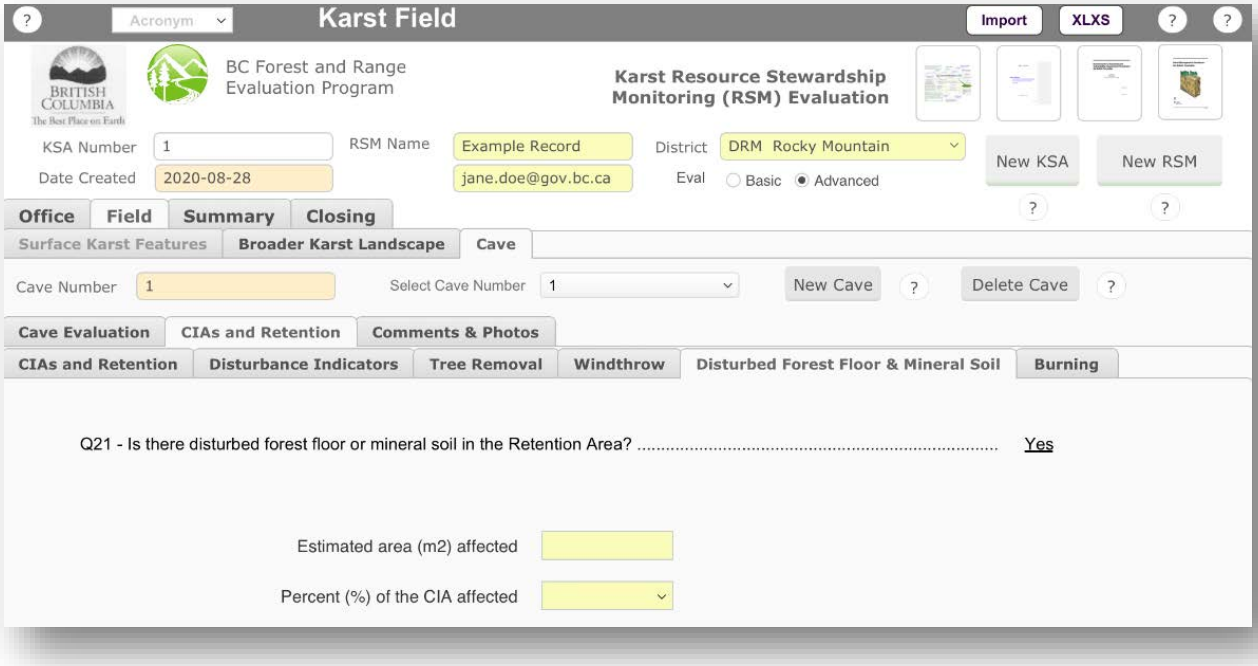
If a retention area is present over the CIA, there is some possibility that windthrow may have occurred depending on site conditions and configuration of the harvest area. Refer to the ***Cave/CIAs and Retention/Windthrow*** tab.



Disturbed Forest Floor and Mineral Soil in Retention Area above CIA

Q21 - Is there disturbed forest floor or mineral soil in the Retention Area? (Yes, No)

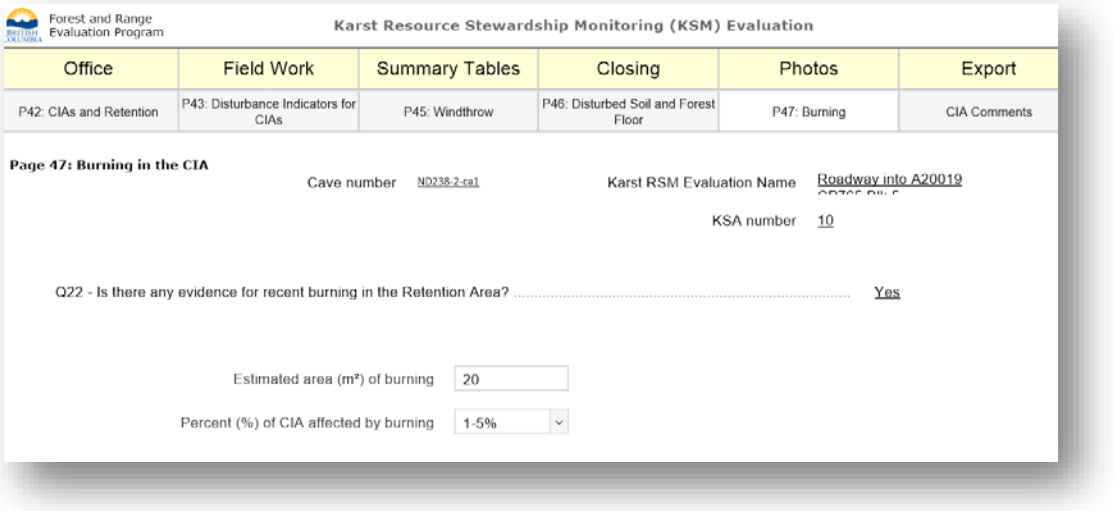
Disturbed mineral soil or forest floor would more likely occur in a harvested area as opposed to a retention area. However, this might depend on the types of forest practices applied to the CIA (e.g., partial harvesting). ***Cave/CIAs and Retention/Disturbed Forest Floor & Mineral Soil*** tab.



Burning in the Retention Area above the CIA

Q22 - Is there evidence of recent burning in the Retention Area? (Yes, No)

Burning could occur in either a harvested or retention area and may or may not be directly associated with forest practices. ***Cave/CIAs and Retention/Burning*** tab.



7.0 Summary Tables

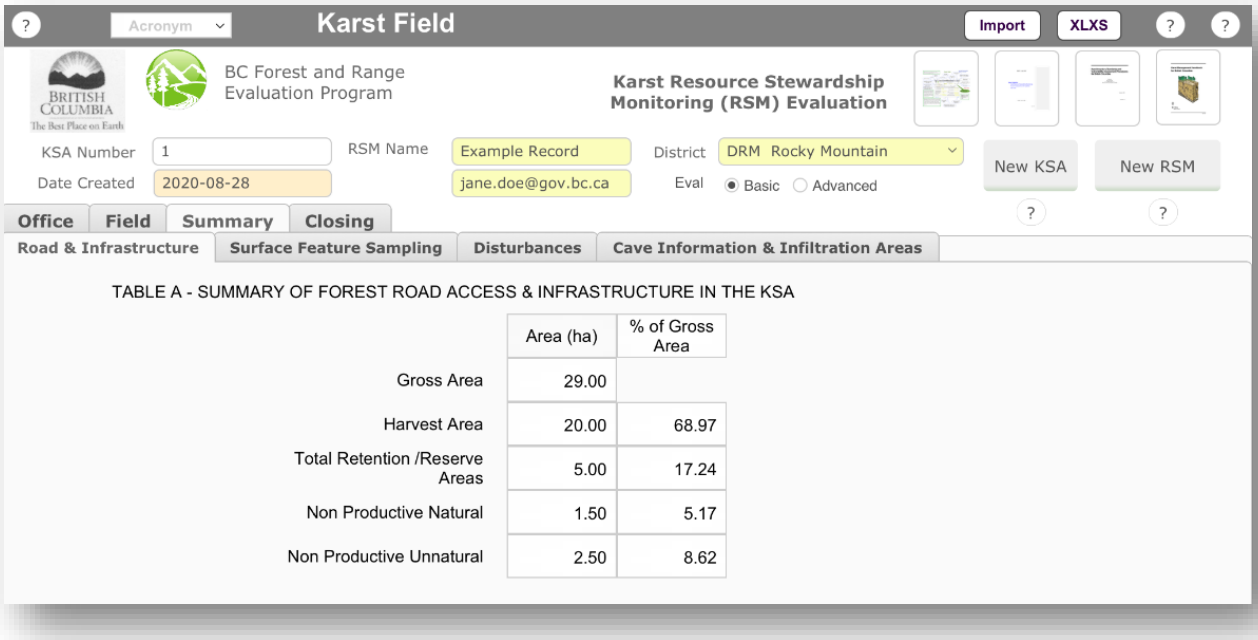
As data is collected during the Karst RSM procedure the digital checklist automatically compiles the data into six summary tables as follows:

- Table A - Proportion of harvest area and road/infrastructure disturbance in KSA
- Table B - Number of SKFs present and sampled in KSA,
- Table C1 - SKFs sampled and their disturbances
- Table C2 - Retention areas surrounding SKF and their disturbances (Advanced Option)
- Table D - Details on BKL sample plots and their disturbances (Advanced Option)
- Table E - Details on caves and CIA if present (Advanced Option)

These tables record the data and analyze this information providing results which are used in the Closing Questions section of the checklist.

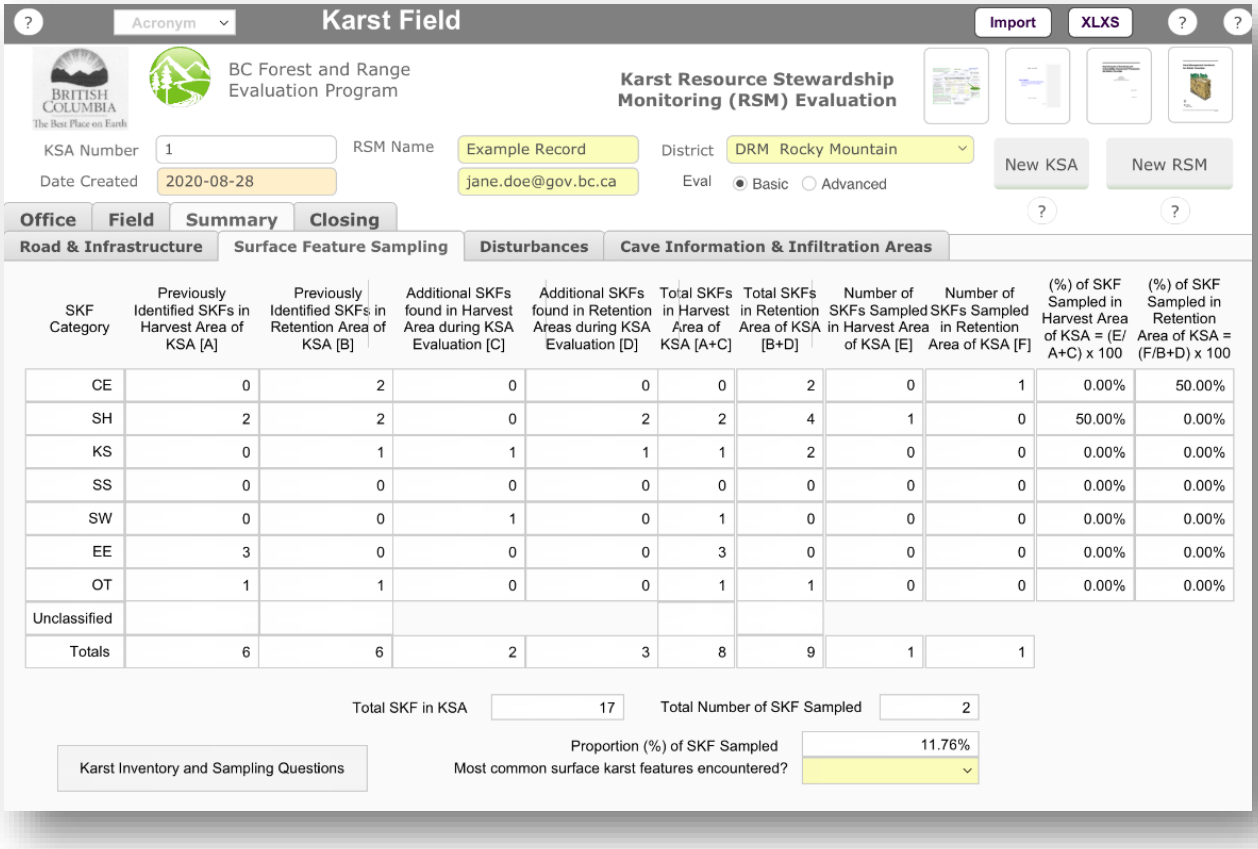
7.1 Table A – Summary of the Forest Road Access and Infrastructure in the KSA

This outlines the total area and percentage of the KSA occupied by the harvested area, roads, and other infrastructure (e.g., quarries/landings). Refer to the ***Summary/Roads & Infrastructure*** tab.



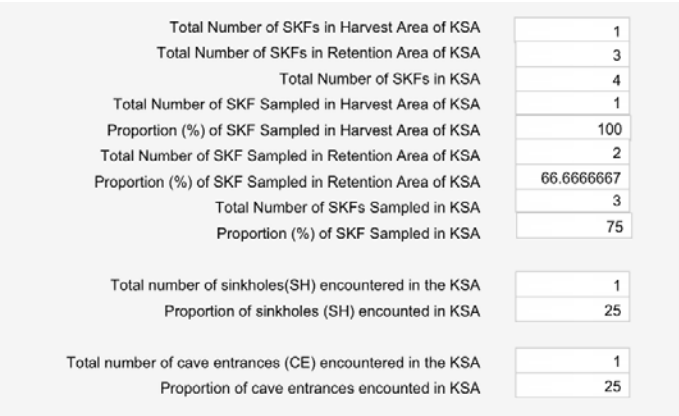
7.2 Table B – Summary of the Surface Karst Feature Sampling in the KSA

This outlines the karst inventory and sampling information collected for SKFs. The types of known and unknown SKFs (i.e., those found during the field evaluation) are listed and totaled. The number of each SKF types sampled is also totaled, and the percentage of each SKF type sampled in the KSA is determined. Refer to the ***Summary/Surface Feature Sampling*** tab.



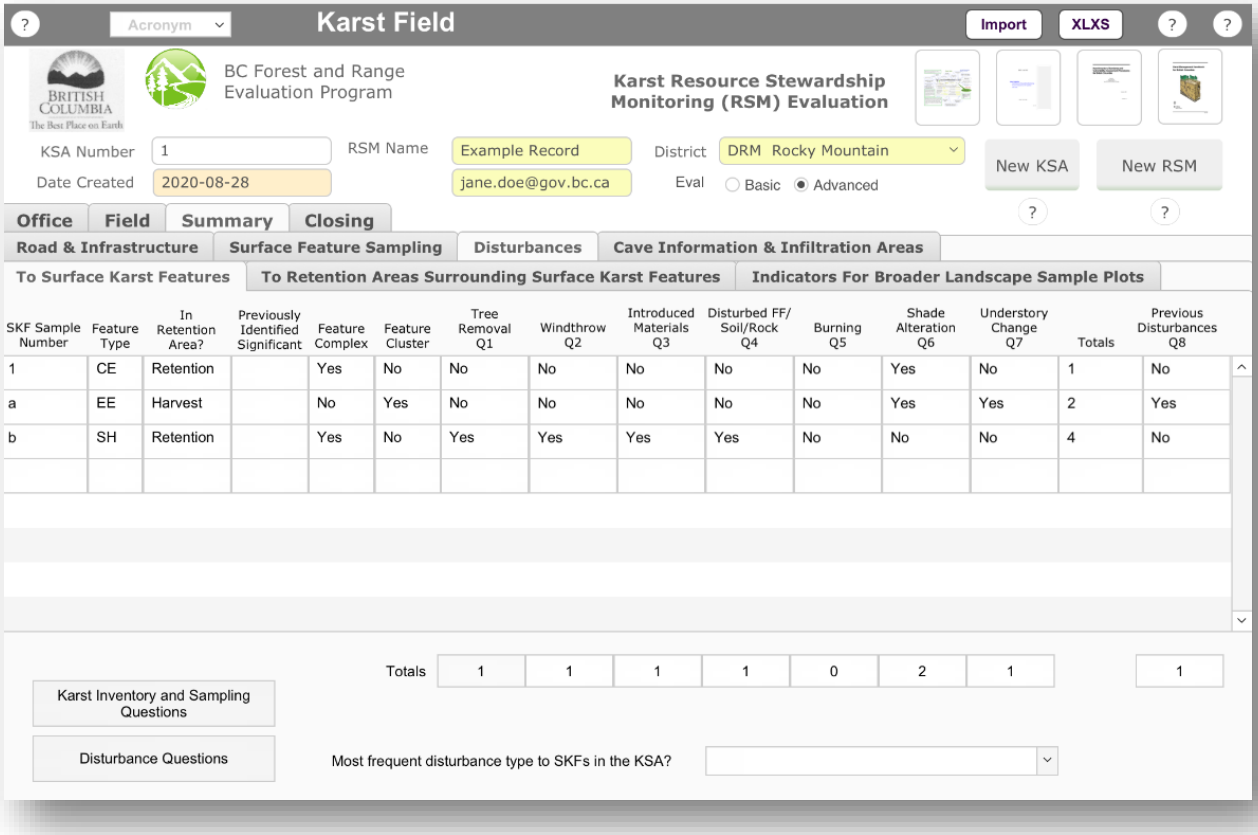
SKF Category	Previously Identified SKFs in Harvest Area of KSA [A]	Previously Identified SKFs in Retention Area of KSA [B]	Additional SKFs found in Harvest Area during KSA Evaluation [C]	Additional SKFs found in Retention Areas during KSA Evaluation [D]	Total SKFs in Harvest Area of KSA [A+C]	Total SKFs in Retention Area of KSA [B+D]	Number of SKFs Sampled in Harvest Area of KSA [E]	Number of SKFs Sampled in Retention Area of KSA [F]	(%) of SKF Sampled in Harvest Area of KSA = (E/ A+C) x 100	(%) of SKF Sampled in Retention Area of KSA = (F/B+D) x 100
CE	0	2	0	0	0	2	0	1	0.00%	50.00%
SH	2	2	0	2	2	4	1	0	50.00%	0.00%
KS	0	1	1	1	1	2	0	0	0.00%	0.00%
SS	0	0	0	0	0	0	0	0	0.00%	0.00%
SW	0	0	1	0	1	0	0	0	0.00%	0.00%
EE	3	0	0	0	3	0	0	0	0.00%	0.00%
OT	1	1	0	0	1	1	0	0	0.00%	0.00%
Unclassified										
Totals	6	6	2	3	8	9	1	1		

When you click on the Karst Inventory and Sampling Questions button on the bottom left of this tab, the following additional information will be viewed:



7.3 Table C1 – Summary of Disturbances to Surface Karst Features in the KSA

This tabulates, for each SKF the feature type, whether it is a feature complex and/or feature cluster, as well as the Yes/No response for the seven disturbance types (tree removal, windthrow, introduced materials, disturbed forest floor/soil/bedrock, burning, shade alteration and understory change). The presence or absence of previous disturbances are also identified. Refer to the ***Summary/Disturbances/To Surface Karst Features*** tab.



When you click on the Karst Inventory and Sampling Questions button on the bottom left of this tab, the following additional information will be viewed:

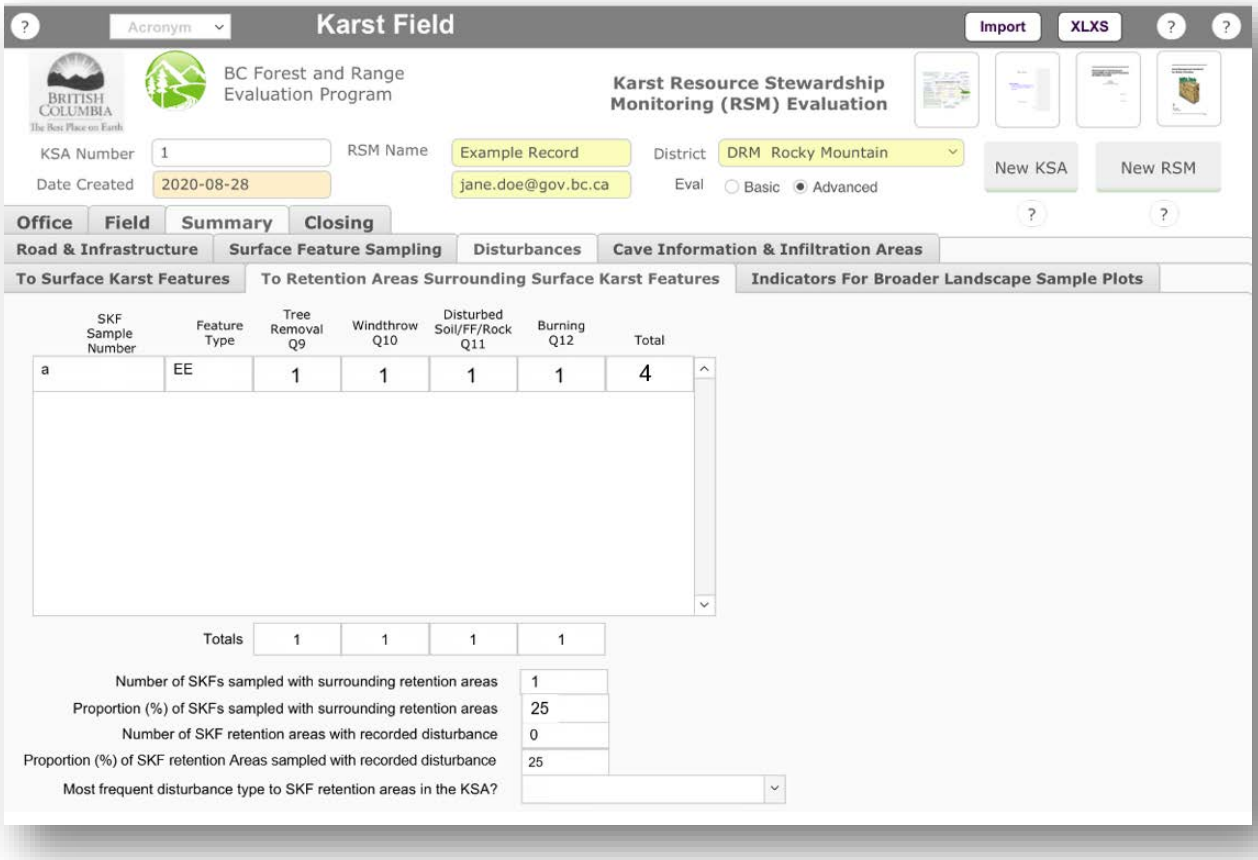
Total number of SKFs sampled	4
Number of SKFs sampled in Harvest Area	2
Number of SKFs sampled in Retention Area	2
Number of SKFs sampled that are part of Karst Feature Complexes in Harvest Area	0
Number of SKFs sampled that are part of Karst Feature Complexes in Retention Area	0
Number of SKFs sampled that are part of Karst Feature Clusters in Harvest Area	1
Number of SKFs sampled that are part of Karst Feature Clusters in Retention Area	0

When you click on the Disturbance Questions button on the bottom left of this tab, the following additional information will be viewed:

Total number of SKFs sampled in Harvest Area with recorded disturbance	1
Proportion (%) of all SKFs sampled in Harvest Area with recorded disturbance	100.0
Total number of SKFs sampled in Retention Area with recorded disturbance	2
Proportion (%) of all SKFs sampled in Retention Area with recorded disturbance	100.0
Total number of SKFs sampled with recorded disturbance	3
Proportion (%) of all SKFs sampled with recorded disturbance	100.0
Number of SKFs sampled in Harvest Area with disturbances other than tree removal and shade alteration	1
Proportion (%) of SKFs sampled in Harvest Area with disturbances other than tree removal and shade alteration	33.3
Number of SKFs sampled in Retention Area disturbed by only shade alteration and/or understory change	0
Proportion (%) of SKFs sampled disturbed by only shade alteration and/or understory change	0
Most frequent disturbance type to SKFs in the KSA?	0
Number of CEs sampled with recorded disturbance	1
Proportion (%) of CEs sampled with recorded disturbance	100.0
Number of SHs sampled with recorded disturbance	1
Proportion (%) of SHs sampled with recorded disturbance	100.0

7.4 Table C2 - Summary of Disturbances to Retention Areas Surrounding SKFs

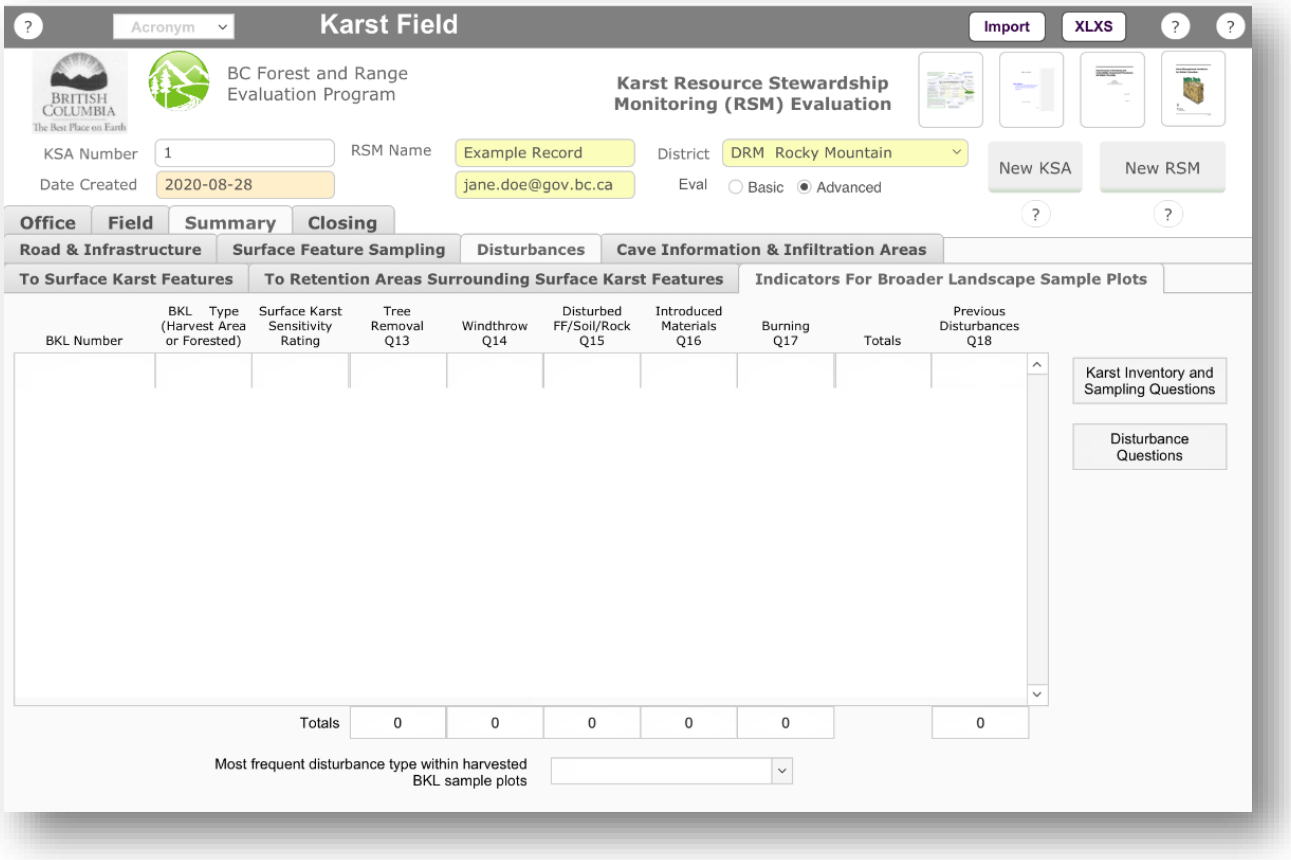
This compiles information on whether SKF have retention areas or not, as well as Yes/No responses to four disturbances within the retention areas - tree removal, windthrow, disturbed forest floor/soil and burning. Refer to the ***Summary/Disturbances/To Retention Areas Surrounding Surface Karst Features*** tab.



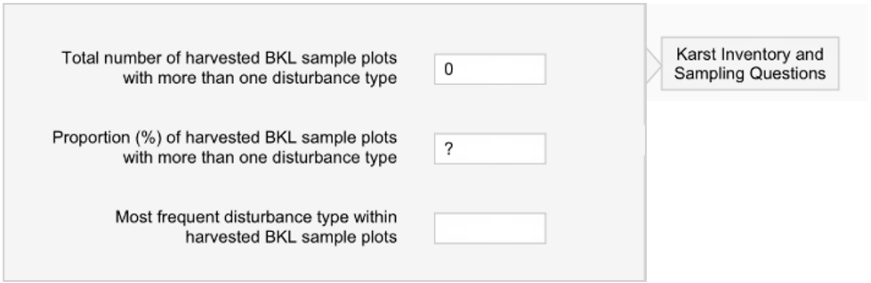
7.5 Table D – Summary of Disturbances for Broader Karst Landscape Plots

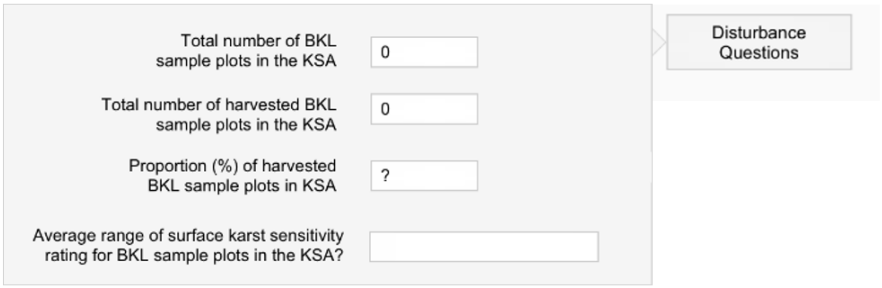
This compiles the number and types of BKL sample plots that were examined along with their respective Surface Karst Sensitivity (SKS) ratings. It also compiles the five disturbances types associated with each BKL sample plot (tree removal, windthrow, disturbed forest floor/soil/bedrock, burning and introduced materials) and whether previous disturbances are present.

Refer to the ***Summary/Disturbances/Indicators for Broader Landscape Sample Plots*** tab.



When you click on the Karst Inventory and Sampling Questions button or Disturbance Questions button on the right side of this tab, the following additional information will be viewed:

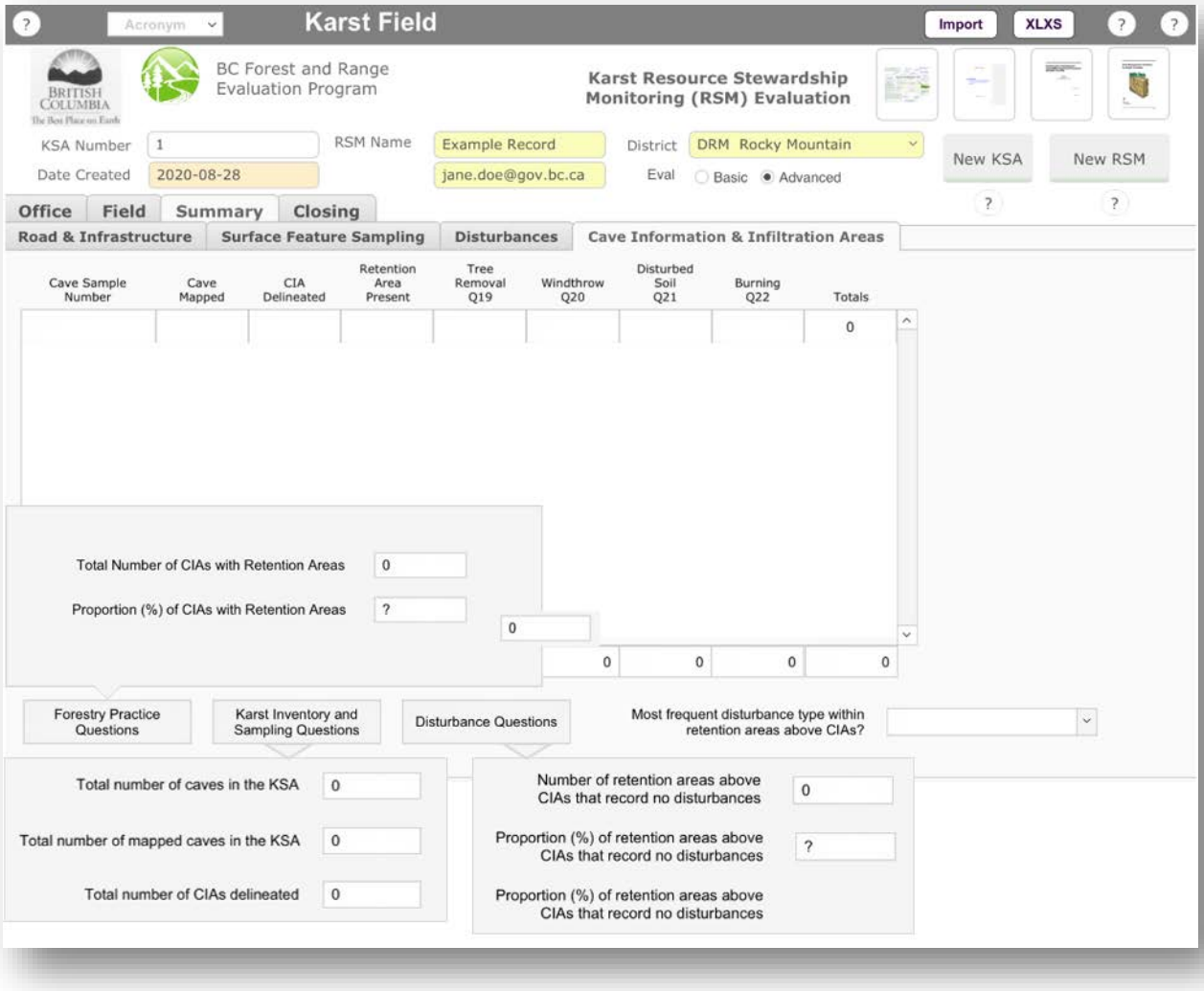



Total number of BKL sample plots in the KSA
0
Total number of harvested BKL sample plots in the KSA
0
Proportion (%) of harvested BKL sample plots in KSA
?
Average range of surface karst sensitivity rating for BKL sample plots in the KSA?
Disturbance Questions

7.6 Table E - Summary of Cave Information, Cave Infiltration Areas and Associated Disturbances

This outlines details on cave and cave infiltration areas (CIAs) and includes data on whether caves have been mapped and CIA delineated. The presence/absence of retention areas, and disturbances to the CIAs are also determined. Refer to the ***Summary/Cave Information & Infiltration Areas*** tab.

When you click on the Forestry Practices button, Karst Inventory and Sampling Questions button, or the Disturbance Questions button, additional information will appear.



8.0 Closing Questions

This last section of the Karst field checklist is located on the ***Closing*** tab. This section draws upon the data collected and analyzed in the six summary tables, and is further sub-divided into the following 5 tabs: ***Disturbances Related to Forestry, Karst Inventory & Sampling, Forestry Practices, Retention Area*** and ***Karst Management.***

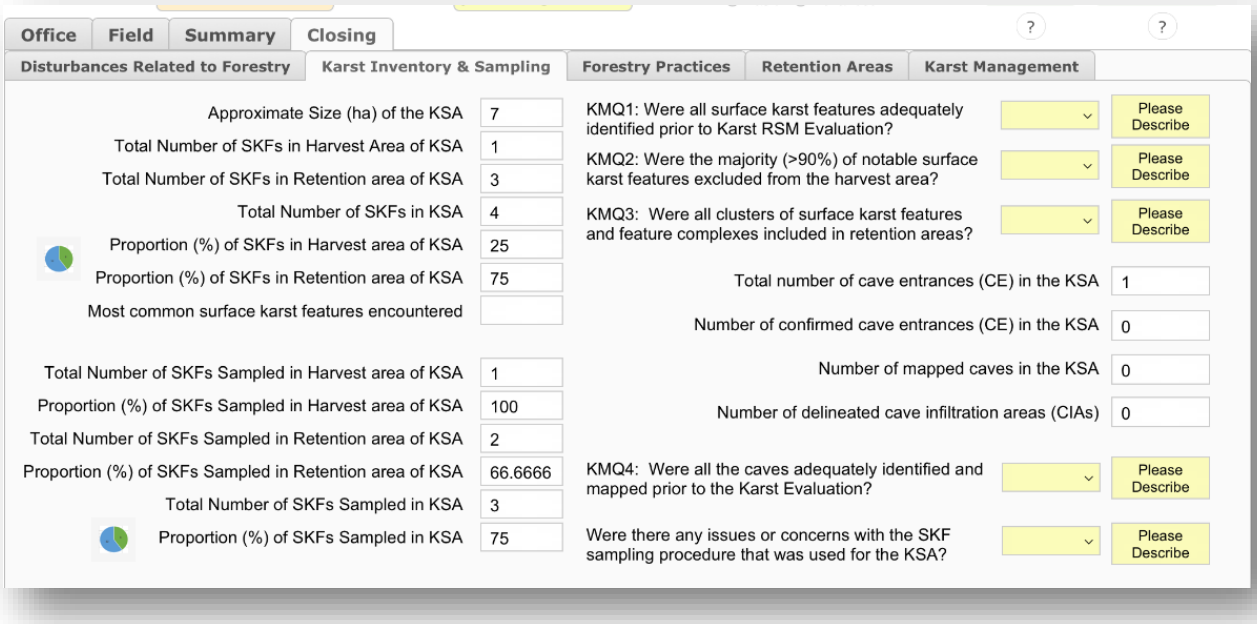
8.1 Karst Inventory and Sampling

Refer to the ***Closing/Karst Inventory & Sampling*** tab. This tab contains closing questions that relate to SKF information and are as follows:

- *KMQ1: Were all surface karst features adequately identified prior to Karst RSM Evaluation? (Yes, No, Unclear). Please describe.*
- *KMQ2: Were the majority (>90%) of notable surface karst features excluded from the harvest area? (Yes, No, Unclear). Please describe.*
- *KMQ3: Were all clusters of surface karst features and feature complexes included in retention areas? (Yes, No, Unclear). Please describe.*
- *KMQ4: Were all caves adequately identified and mapped prior to the Karst RSM Evaluation? (Yes, No, Unclear). Please describe.*
- *Where there any issues or concerns with the SKF sampling procedure that was used for the KSA? (Yes, No, Unclear). Please describe.*

To answer these questions, review the information presented on this page (which is taken directly from Summary Tables A, B, C1, D and E.) Information presented on this tab includes:

- Number and types of SKFs evaluated in the harvest versus retention areas,
- One pie-chart indicating the proportion of SKFs sampled in the harvest versus retention,
- Another pie-chart showing the total number of SKF's sampled in the KSA (harvest versus reserve),
- The most common type of surface karst feature encountered must be entered based on your review of the Summary Table C1, and
- The total number sampled and what proportion of the population this represents.



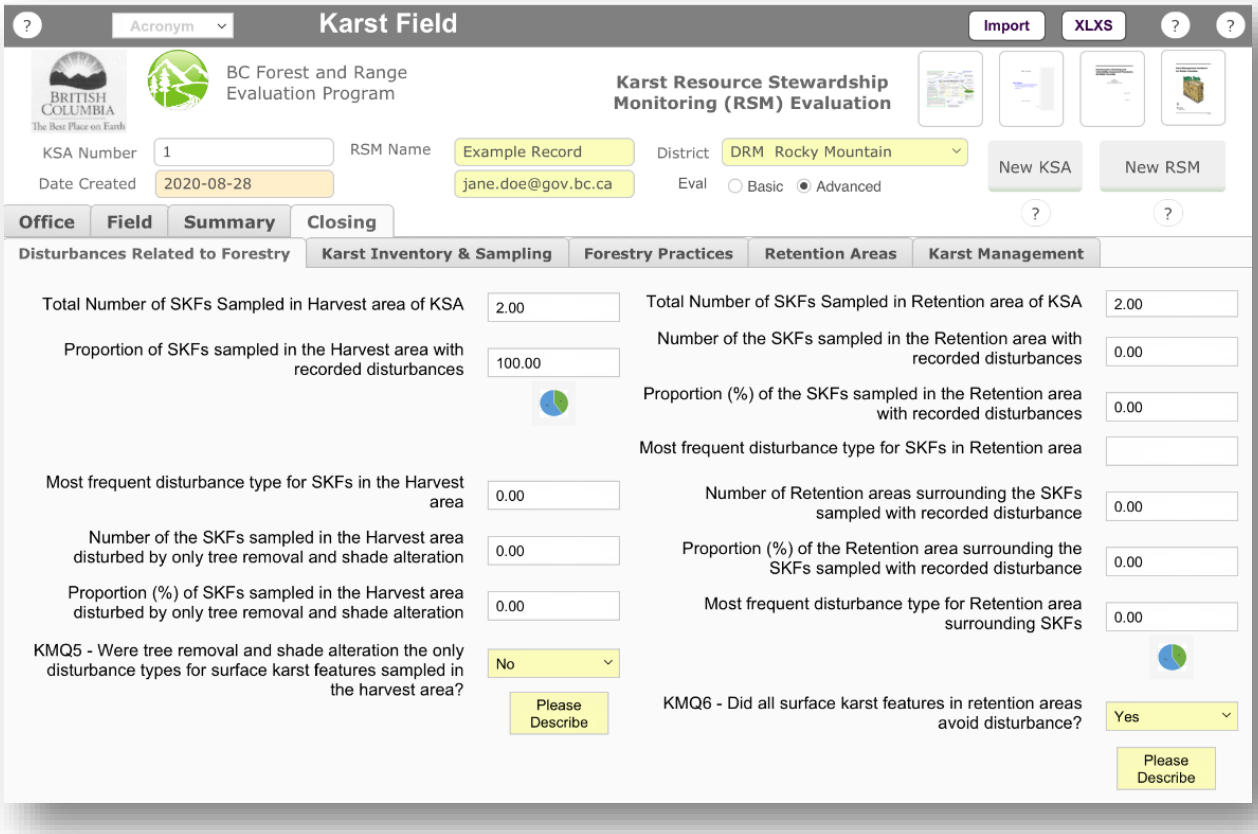
8.2 Current Forestry Practices and Related Disturbances

Refer to the ***Closing/Disturbances Related to Forestry*** tab. The first question in this section focuses on the current forestry disturbances summarized in Summary Table C1. You can click on the pie-chart icon to view a pie-chart that shows the proportion of SKFs sampled in the Harvest area with recorded disturbances. This information is used to answer the following question:

- *KMQ5: Were tree removal and shade alteration the only disturbance types for surface karst features sampled in the harvest area? (Yes, No, Unclear). Please describe.*

The second question relates to retention areas surrounding SKFs and can be answered if this data was collected as part of an Advanced Option. You can click on the pie-chart icon on the bottom right of the tab, to view a pie-chart showing the types of disturbances recorded in these retention areas (No Disturbance vs. Shade Alteration vs Windthrow and Other Disturbances). This information is used to answer the following question:

- *KMQ6: Did all surface karst features in retention areas avoid disturbance (Yes, No, Unclear)*

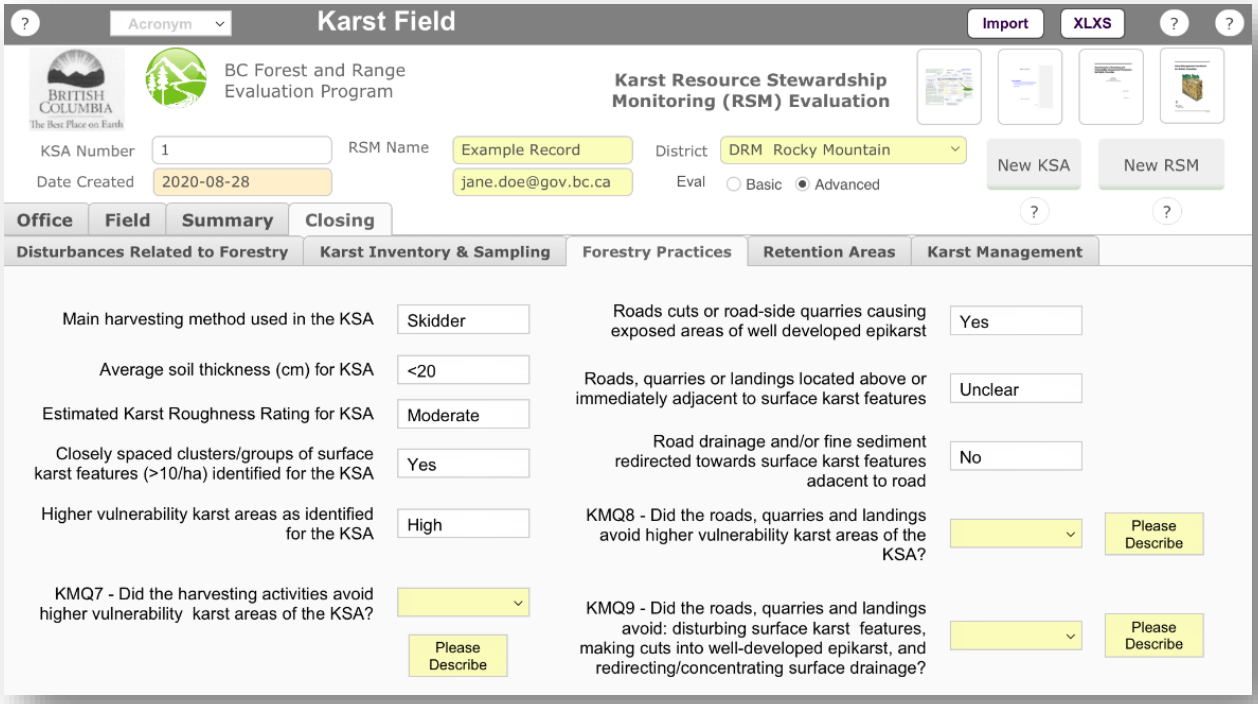


8.3 Forestry Practices

Refer to the ***Closing/Forestry Practices*** tab. The closing questions on Forestry Practices provide an overall assessment of forestry activities in the KSA and determines what types of forestry practices have been applied to the karst resources in the KSA.

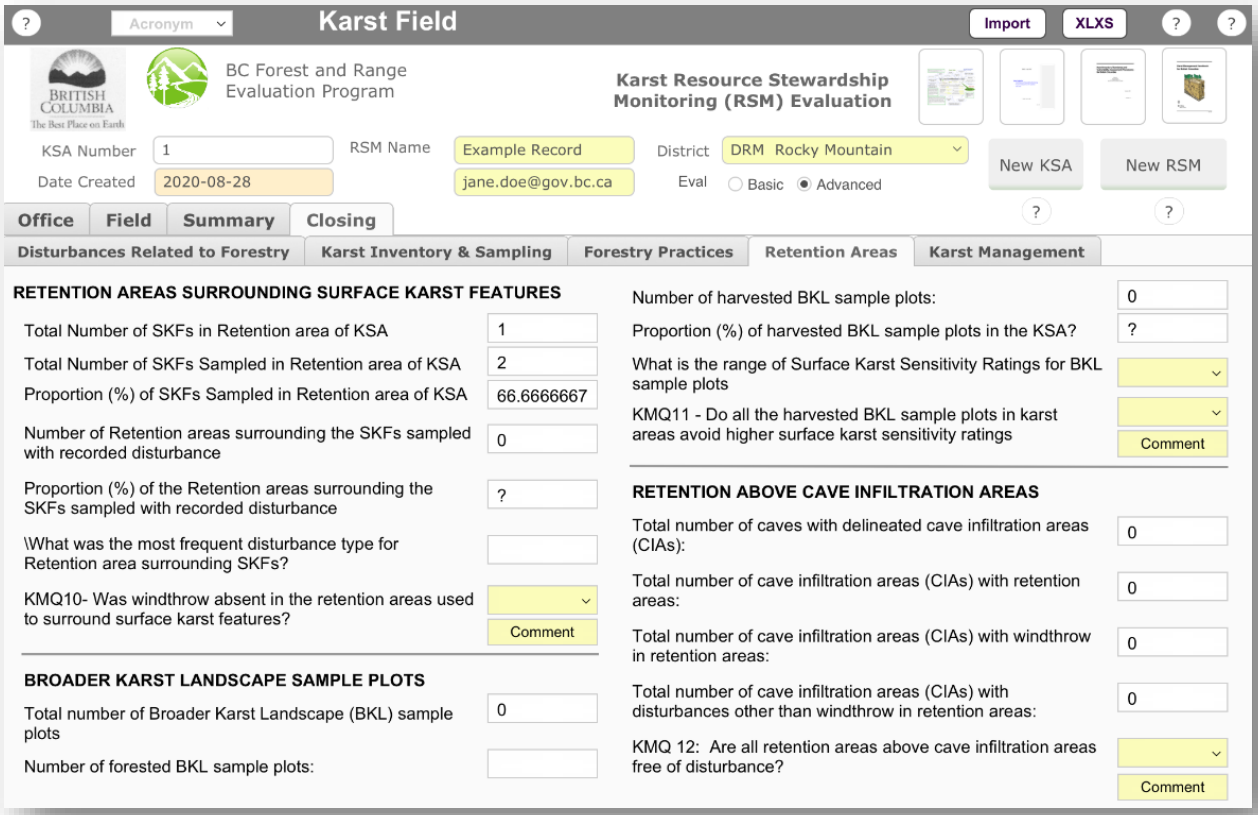
- *KMQ7: Did the harvesting activities avoid higher vulnerability karst areas of the KSA? (Yes, No, Unclear). Please describe.*
- *KMQ8: Did the roads, quarries and landings avoid higher vulnerability karst areas of the KSA? (Yes, No, Unclear). Please describe.*
- *KMQ9: Did the roads, quarries and landings avoid: disturbing surface karst features, making cuts into well-developed epikarst, and redirecting/concentrating surface drainage? (Yes, No, Unclear). Please describe.*

To answer these questions, review the presented information about harvesting method, soil thickness and roughness of KSA, estimated Karst Roughness Rating, and road construction methods.



8.4 Questions on Advanced Components: Retention Areas, BKL and CIA

If any of the advanced components were undertaken, please refer to the ***Closing/Retention Areas*** tab. To assist in the responses for Retention Areas, BKL and CIA, related information will be presented from Summary Tables C2, D and E, respectively.



If retention areas were evaluated, the following question should be answered:

- *KMQ10: Was windthrow absent in the retention areas used to surround surface karst features? (Yes, No, Unclear). Provide comment.*

If Broader Karst Landscape plots were completed, the following questions should be answered:

- *What is the range of Surface Karst Sensitivity Ratings for BKL sample plots (Low, Low-Moderate, Low to High, Moderate, Moderate-High, Moderate to Very High, High, High to Very High, Very High, Unclear). Provide comment.*
- *KMQ11: Do all the harvested BKL sample plots in karst areas avoid higher surface karst sensitivity ratings (Yes, No, Unclear). Provide comment.*

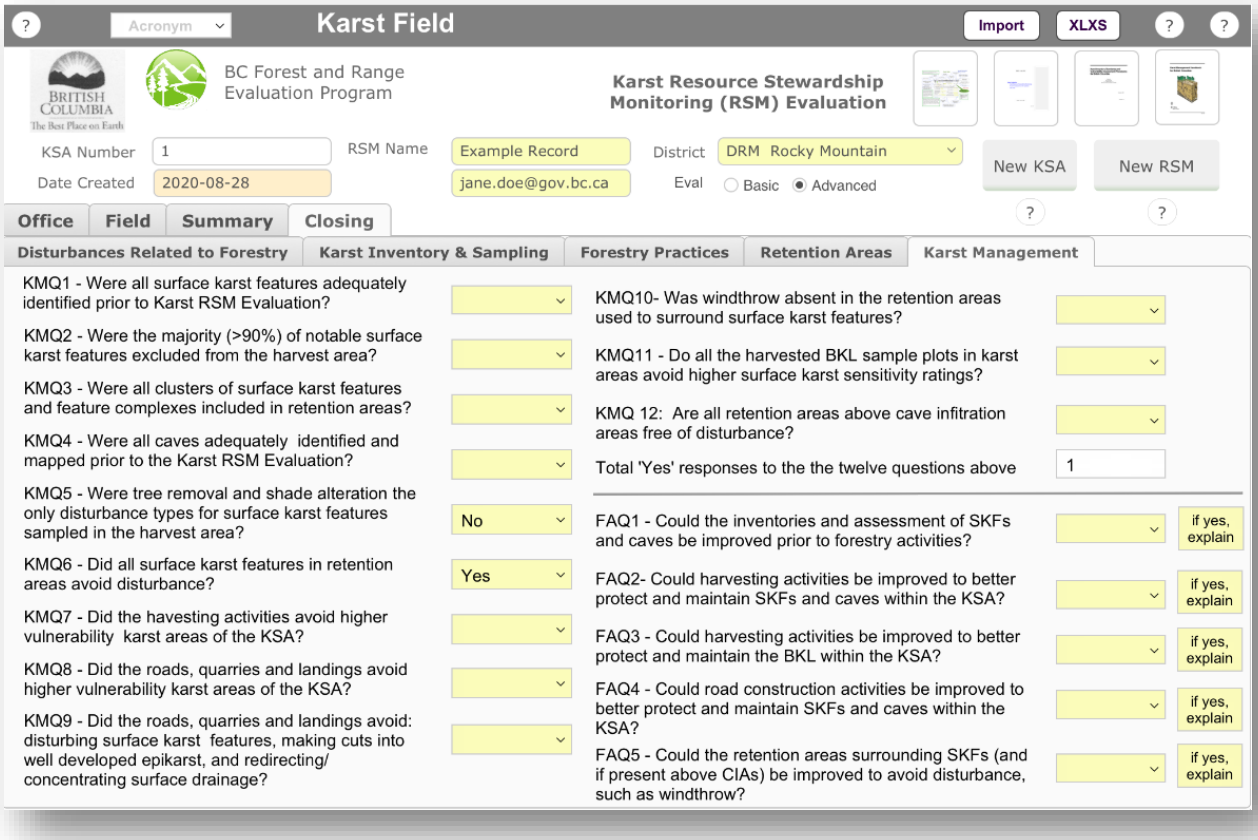
If Cave Infiltration Areas were evaluated, the following question should be answered:

- *KMQ12: Are all retention areas above cave infiltration areas free of disturbance? (Yes, No, Unclear). Provide comment.*

8.5 Karst Management

Refer to the ***Closing/Karst Management*** tab. The goal of this final section is to examine how effective the forest practices have been in protecting the karst resources within the KSA and whether improvements could be made. Answers to the previous closing questions are presented here for context and to assist in evaluating karst management overall. Additionally, you may wish to refer to the Karst Management Handbook of BC to review best management practices. You can click on the icon on top right of the Karst field checklist to view a pdf of the handbook. The questions relating to karst management are as follows:

- *FAQ1: Could the inventories and assessment of SKFs and caves be improved prior to forestry activities? (Yes, No). If so, please explain.*
- *FAQ2: Could harvesting activities be improved to better protect and maintain SKFs and caves within the KSA? (Yes, No). If so, please explain.*
- *FAQ3: Could harvesting activities be improved to better protect and maintain the BKL within the KSA? (Yes, No). If so, please explain.* (This question only visible if a BKL was conducted).
- *FAQ4: Could road construction activities be improved to better protect and maintain SKFs and caves within the KSA? (Yes/No). If so, please explain.*
- *FAQ5: Could the retention areas surrounding SKFs (and if present above CIAs) be improved to avoid disturbance, such as windthrow? (Yes, No). If so, please explain.*



9.0 Closure and Limitations

It is expected that continuous improvements to the Karst effectiveness evaluation will be made after piloting in the first year of application. The field checklist and this protocol will undergo refinements and enhancements. It is also anticipated that these changes will be peer reviewed by others and experts in karst science. To date the Karst field checklist has not been field trialed in BC Interior karst settings, which can differ from those on the coast in several important ways (e.g., lack of surface karst expression and thick soil cover). Therefore, some refinements maybe required if used in these regions.

10.0 References

BC Ministry of Forests. 2003. Karst Management Handbook for British Columbia. Province of British Columbia, Victoria, BC.

Ramsey, C.L., Griffiths P.A and Stokes, T.R. 2014. Multi-rotor unmanned aerial vehicles (UAVS) and compact high-resolution digital cameras: a promising new method for monitoring changes to surface karst resources. Acta Carsologica, 43/2-3, p 269-286.

Resource Information Standards Committee (RISC). January 2003. Karst Inventory Standards and Vulnerability Assessment Procedures for British Columbia (Version 2.0). Victoria, BC.

Stokes, T. 2016. Preliminary Analysis of Surface Karst Feature Data from Northern Vancouver Island. Forest Range and Practices Extension Note #37. Victoria, BC. 7 p.

11.0 Glossary

Aspect – Measures the orientation of a slope by means of compass points and indicates whether the slope is exposed to the north, south, east, or west, or any point between. Level ground has no aspect.

BEC Zone – Biogeoclimatic zone.

Cave – A natural cavity in the earth that connects with the surface, contains a zone of total darkness, and is large enough to admit a human. For the purposes of cave management, this term includes any natural extensions, such as crevices, sinkholes, pits, or any other openings, that contribute to the functioning of the cave system. If a cave fills with water or becomes full of ice or sediment and is impenetrable, the term still applies but needs qualification.

Cave entrance – Surface openings large enough to admit a human being, connecting to interior cavities that contain a zone of complete darkness. A cave entrance is part of the cave or cave system and may be nested within one or more other surface karst features. For example, a cave entrance may be located within a sinkhole - examples of nested or compound karst features.

Cave infiltration area - The infiltration area above a cave is the ground surface that is primarily influenced by diffuse percolation of water. The location, size and shape of the infiltration area above the cave can be projected to the surface using cave maps based on a 45˚angle on either side of the outside wall of the cave passage or chamber.

Catchment - The surface area drained by various-sized watercourses. A karst catchment for a spring or series of outflows consists of both non-karst (allogenic) and karst (autogenic) recharge.

Cutblock – An administrative area of managed forest land where timber is harvested from all or a portion of the area.

DBH – The diameter of a tree at breast height; measured at a height of 1.3 m above the ground on the upslope side of the tree.

Damage - Any human-induced departure from the range of natural variability, within a recent geological time frame, which can fundamentally and detrimentally alter the karst ecosystem or component karst features.

Degradation - A reduction in the quality, integrity or viability of particular natural values of a karst feature, process or system, resulting from disturbances caused by human activity.

Disturbance - Any change to a karst feature, process or system caused by human or natural activities. Most of the Karst RSM procedure is focus on recent disturbance caused by forestry activities.

Epikarst - The upper surface of karst, consisting of a network of intersecting fissures and cavities that collect and transport surface water and nutrients underground; epikarst depth can range from a few centimetres to tens of metres. An Epikarst exposure is a bare or uncovered epikarst surface; an outcrop. Epikarst cavities are the vertical solution openings in epikarst.

Feature cluster - Two or more distinct surface karst features that are physically separated on the surface by a distance no greater than twice the greatest dimension of the closest other neighbour. The component features do not touch or overlap each other.

Feature complex - A combination of two or more surface karst features that are touching or overlapping each other; nested karst feature - a karst feature located inside a larger enclosing feature.

Karren – Channels or furrows separated by ridges resulting from solution on bedrock surfaces; the term is also used broadly to describe a variety of superficial solution forms on the surface of bedrock, including grikes.

Karst - A terrain, generally underlain by limestone, in which the topography is formed chiefly by the dissolving of rock, and which is commonly characterized by karren, closed depressions, subterranean drainage, and caves. Inter-feature Karst Terrain (IFKT) includes all the karst areas that occur between surface karst features and epikarst exposures.

Karst Field Assessment (KFA) – An assessment or characterization of karst terrain and specific karst resource features in association with a planned harvest operation.

Karst inventory – The identification, classification and documentation of the location and characteristics of karst terrain and specific karst resource features and values.

Karst (resource) feature – A distinguishable surface or subsurface element of a karst system. Surface karst features are those features of the karst landscape that can be viewed by an observer on the ground up to the threshold of daylight in subsurface openings, including cave entrances. Subsurface

karst features are those that are beyond the threshold of daylight. Smaller scale negative relief karst features are defined as those distinguishable surface karst elements with a mean size (diameter/length/width) of at least 1 m.

Karst resources – Refers to all components of a karst system, including the physical, biological, and aesthetic aspects of a karst landscape.

Karst polygon – A karst area that can be identified on a map and is relatively uniform in broader karst landscape characteristics. Typically, karst polygons must be greater than 1 ha in size to be mapped at a scale of 1:5000.

Karst Sample Area (KSA) – A continuous or uninterrupted karst area of more than 1 ha inside a cutblock and/or outside the cutblock and within 100 m of the cutblock boundary; a contiguous karst area of more than 1 ha situated along an access road leading to a cutblock and within 100 m of the road if the vulnerability of the karst terrain is high; a contiguous karst area of more than 1 ha situated along an access road leading to a cutblock boundary and within 50 m of the road if the vulnerability of the karst terrain is less than high. Note: The karst sample unit contains the population of karst features to be sampled.

Karst Sensitivity - The inherent susceptibility of a karst feature, process or system to degradation resulting from disturbances caused by human activities, irrespective of any existing threats of such disturbance occurring.

Karst spring – A spring emerging from karstified limestone. Karst spring outflow – the spring discharge opening, either in rock or soil, or both.

Monitoring - The act of measuring change in the state, number or presence of the characteristic(s) of something. Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system. It entails the comparison of objects (e.g., organisms) and processes (e.g., streamflow) before and after management actions to determine the effect of those actions upon the ecosystem. Monitoring of karst is the repeated observation, through time, of selected features and/or values in the karst ecosystem to determine the state of the system.

Reach – A length of a stream or watercourse having similar channel morphology, channel dimension, and gradient.

Rising Stream – A channel that occurs below a karst spring that can be seasonal or present all year round.

Sinkhole - A topographically closed karst depression, wider at the rim than it is deep; commonly of a circular or elliptical shape with a flat or funnel-shaped bottom. For sampling purposes, a sinkhole must have a deepest point at least 2 m below the surrounding landscape, and have a width greater than 2 m. Sinkhole with a distinct (micro)climate – a sinkhole that exhibits conditions of temperature and relative humidity that significantly differ from those measured in surrounding areas.

Sinking stream – A small stream that disappears underground at a karst insurgence, usually a swallet. A swallet is the location where a stream sinks underground, often associated with a stream flowing into a cave entrance; also swallow hole. A subset of surface karst features.

Sinking watercourse – A watercourse that sinks into the subsurface at a distinct sink point, and possesses one or more of the following characteristics: poorly or non-defined channels (including flow over an organic bed); exhibits no evidence of scouring or alluvial deposition; or flows on the surface for less than 100 meters. As a minimum threshold, a sinking watercourse follows a confined, linear drainage course with a distinguishable cross-sectional low point, accompanied by the presence of hydrophytic vegetation (plants that thrive in saturated soils).

Slash (logging) – The tree residue left on the ground as a result of trees or other vegetation being altered by forest practices. Slash includes logs, splinters or chips, tree branches and tops, uprooted stumps, and broken or uprooted trees or shrubs.

Stream – Any reach, flowing on a perennial or seasonal basis, with a continuous channel bed (whether the bed or banks of the reach are locally obscured by overhanging or bridging vegetation or soil mats) that is either scoured by water or contains observable deposits of mineral alluvium.

Stream bank – The rising ground bordering a stream channel.

Streambed – The bottom of the stream below the usual water surface.

Stream channel – Means the area between the outermost opposing stream banks measured at the point where rooted terrestrial vegetation begins.

Stream width – The average distance across the stream channel measured at right angles to stream flow.

Surface Karst Feature (SKF) sample – An individual karst feature within a representative selection of a population of karst features of the same type that is examined or evaluated to gain statistical information about the whole population inside a karst sample unit. There are seven types surface karst features that might populate a karst area and include: cave entrances, sinking streams and sinking watercourses, sinkholes, epikarst exposures, karst springs, and other surface karst features.

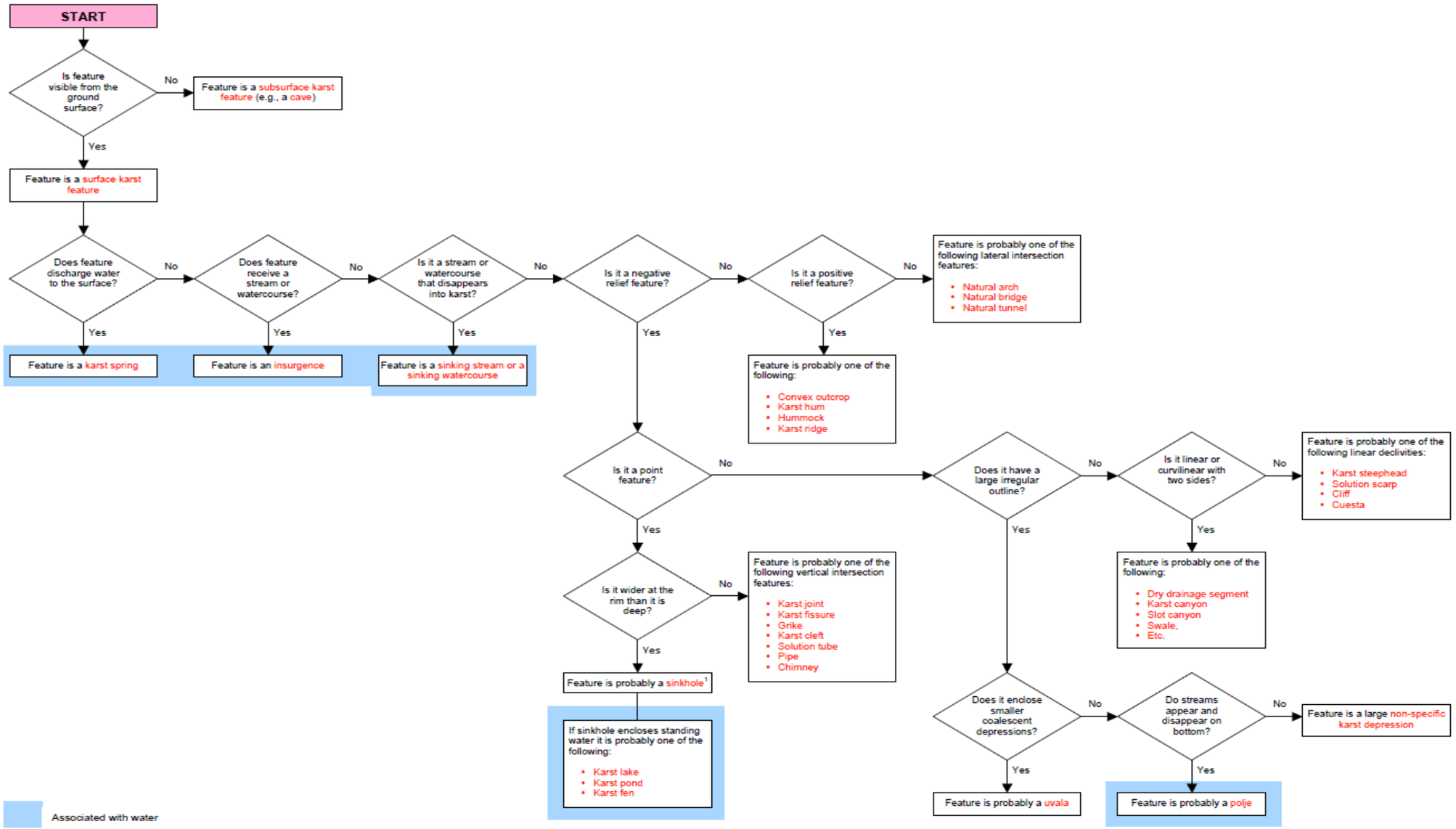
Understory - Any plants growing under the canopy formed by another layer of plants, herbaceous, bryophyte, shrub, and grass vegetation under a tree canopy.

Vulnerability – The degree to which a karst feature, process or system is actually threatened with degradation due to disturbances caused by existing or likely human activities, given its inherent sensitivity.

Vulnerability assessment - A hazard assessment methodology for evaluating the relative ease with which a karst ecosystem might be changed negatively (or harmed) by an imposed external activity.

Vulnerability Assessment Procedures (VAP) – A systematic four-step method for determining a vulnerability rating for a karst polygon using three major criteria: epikarst sensitivity, surface karst sensitivity, and subsurface karst potential. The procedure also allows for the integration of three modifying factors: fine-textured, erodible soils; karst roughness; and unique or unusual karst flora/fauna sites.

APPENDIX 1. Karst Features Classification Flowchart



APPENDIX 2 – Random Sampling Techniques

The objective of random sampling is to select karst features of a population set by chance so that there is no subjective determination to bias the sample. The selection procedure must be such that all the individual items in the population, or in certain subgroups within the population, are given an equal and independent chance to be selected into the sample. One of the most effective and practical ways to insure equal and independent probabilities of selection is to use a table of random sampling numbers, random sampling using Excel or a Smart Phone App. Prior to applying a random sampling method, the karst features to be sampled must be counted and/or sequentially numbered.

The following example provides a method for selecting five SH from ten SH this using Excel, a smart phone app and two dice. First the ten sinkholes are numbered in the first Column and the =RAND() function is used to generate random number between 0 and 1 to six decimal places. Instead of using Excel it is possible to generate similar random numbers using a Smart Phone App. Alternatively, two dice could be used to generate random number from 1-12. In all cases the SHs with lowest five values are chosen as the samples.

Excel

SKF Number	Random Number (0-1)
SH1	0.848771
SH2	0.897327
SH3	0.966404
SH4	0.707068
SH5	0.888874
SH6	0.257098
SH7	0.29464
SH8	0.592552
SH9	0.506569
SH10	0.861165

Smart Phone App

SKF Number	Random Number (0-100)
SH1	83
SH2	34
SH3	57
SH4	67
SH5	5
SH6	78
SH7	99
SH8	25
SH9	56
SH10	23

Two Dice

SKF Number	Random Number (1-12)
SH1	5
SH2	7
SH3	10
SH4	11
SH5	2
SH6	7
SH7	5
SH8	8
SH9	8
SH10	12

APPENDIX 3 – Guide for Using the FilemakerApp and the Karst Field Checklist

The Karst field checklist has been complied using Filemaker Pro software and can be used in I-Pads with the Claris Filemaker Go App (version 18 or 19). This brief guide provides the user with information on how to use the digital checklist on an I-Pad and includes uploading the checklist, renaming and sorting files, plus navigating and saving data.

The Claris Filemaker Go App (Version 19) must be downloaded from the I-Pad App store. It is free but will only work on more recent iPads with iOS 13.2 or newer. Version 18 may be used on older iPads.

Setting up Files on Dropbox - Transfer the "Karst field checklist" and "Karst Reference Documents 2020" (both are. fmp12 files) to a Dropbox.

Uploading Field Checklist – In Dropbox, double tap these files and it will be unloaded for use. Then find the open tool and open the Karst field checklist file with Filemaker Pro. It should now be loaded onto the app and ready for use.

Navigating in Filemaker – The tabs of the app are set up for ease use through the check list procedure starting with Office and then progressing to Field Work, Summary Tables and the Closing.

- To start: When you create a "New RSM" it starts with a new KSA in place and ready to go. (You do not need to add a "New KSA". If you do click on "New KSA" at this point, then you will have two KSAs started). It also creates a new SKF, BKL & Cave record for that KSA. The names of these can be changed.
- The Evaluation Type ("Eval") on Page 1 identifies the level of evaluation for the KSA – Basic or Advanced. It defaults to Basic. With the Basic Evaluation, the only field work that should be accessed is SKF Info, SKF Disturbance Indicators, BKL and Cave Evaluation. To access BKL disturbances an "Advanced" evaluation is required. Likewise, to access retention areas and their disturbances, an Advanced Evaluation is required.
- For multiple KSAs under an RSM, you can then add a New KSA to the existing RSM, likewise for SKF, BKL & Cave for the current KSA.
- If you wish to return to an old Karst RSM Evaluation, SKF, BKL or CIA, you can you use the navigation tools at the bottom centre. Click on the centre "O", select "Show All Records" scroll to the record of choice.

Keyboard Use - When adding a number or text, a keyboard will appear at bottom. When finished with keyboard hit 'Done'. Pick lists are used in many cases to speed up infilling of data and to ensure consistency.

Photos, Audio and Sketches – Photos can be added during most phases of the field work for SKF, BKL and CIA evaluations. These photos use the camera in the device. Sketches or hand-written text can also be added using the Signature mode, while Audio can also be added for a site if required.

Exporting, Saving and E-mailing Data – Export only using the XLXS Button on the top right. Click "done" to see the next table. A number of separate tables will be presented this way, and will each need to be saved individually.

Karst Help

Karst, under the Forest and Range Evalua3on Program (FREP) has been developed primarily to assess the impact on Karst resources throughout the province.

Learn How To Use Your iPad
Identify Your iPad Model

Acronyms & Definitions

Reference Document Thumbnails.

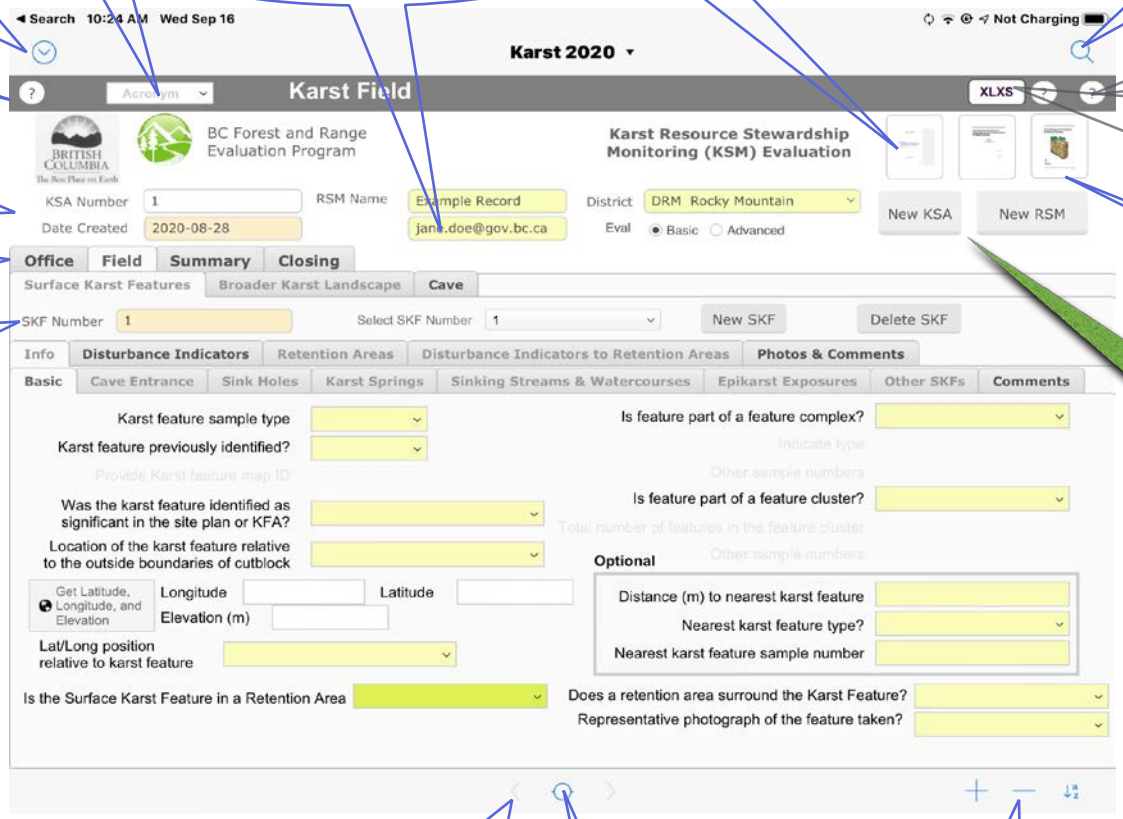
Search for a subset of Sites by example using range operators

File Menu

Your eMail Address

All Version Numbers

Symbols to use with Search above



Sample KSA number is unique to RSM Name and generated automatically

Export records to XLXS spreadsheet file. One file per table all records

Select Tabs to examine each aspect of the site

Karst Protocol

SKF, BKL & Cave Numbers can be changed, but an initial record for each is assigned when a new KSA number is created.

Start Here

New RSM & KSA

Hardware: iPad 5G, Pro or Mini 4 or Air 2 or newer with cellular as this includes GPS also. "Apple Care +" at 3me of purchase and a case like the Life Proof are recommended for field work. Note that earlier iPads will show an updated iOS less than iOS 13.2

Yellow fields are editable.
White fields are calculated.
Green fields are required
Orange fields are calculated but can be over written.

Software Apps: FileMaker Go 19 & pads 13.2 or newer, Google Earth (clear cache, review area of interest at all appropriate zoom levels, close un3l off-line. What remains in the cache can be used in the field), Clinometer HD, Theodolite (op3onal), Dropbox (op3onal), Find My (to locate lost iPads). Backups to Dropbox or a computer of your Karst database are recommended on a regular basis. Use

Move Left & Right through KSA Records

Delete all or some KSA records. Please use New KSM not +

KSA Record Selector: Record 1 of 3 / 6
The currently selected set of records is 3 of a total of 6. You are viewing record 1.

APPENDIX 4 – Measuring the Size of Cave Entrance and Other Openings

Profile view

Circular entrance of radius r

$$A = \pi r^2$$

Elliptical entrance of height h and width w

$$A = \pi hw$$

Parabolic entrance of height h and base b

$$A = \frac{2}{3} hb$$

Rectangular entrance of height h and width w

$$A = hw$$

Parallelogram-shaped entrance of height h and base b

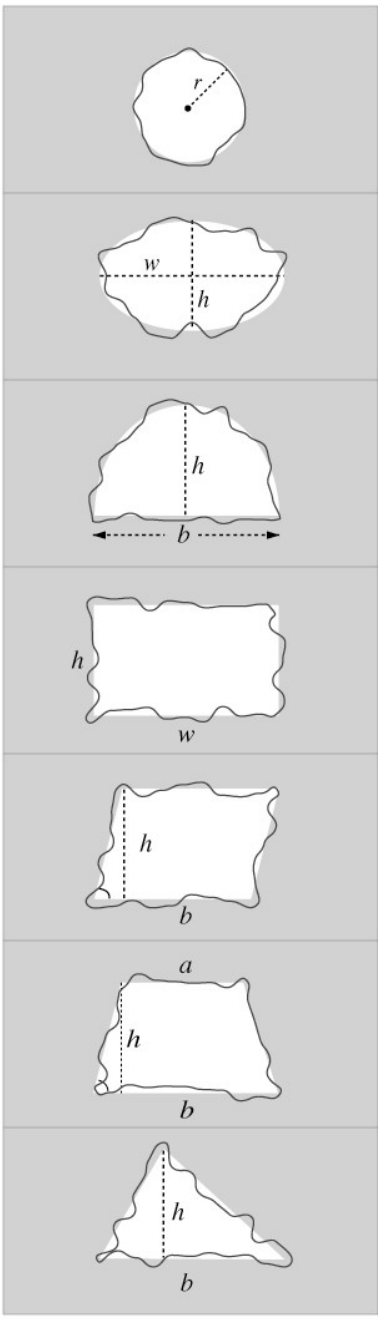
$$A = bh$$

Trapezoidal entrance of height h and parallel sides a and b

$$A = \frac{1}{2} h(a + b)$$

Triangular entrance of height h and base b

$$A = \frac{1}{2} bh$$



Note: For inventory purposes, the cross-sectional area of a horizontal or sub-horizontal cave entrance is visually estimated at the vertical plane formed by the most probable dripline. The dripline is a line on the ground at a cave entrance formed by drips from the rock above.

Figure D2. **Cross-sectional area of cave entrances with horizontal or sub-horizontal aspect.**

Plan view

Circular entrance of radius r

$$A = \pi r^2$$

Elliptical entrance of length l and width w

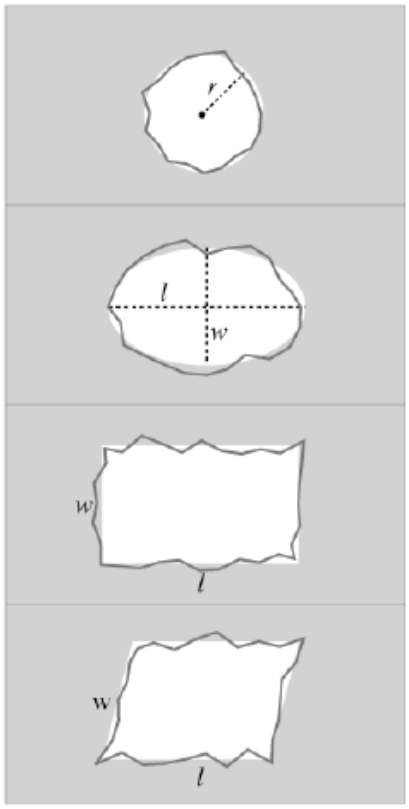
$$A = \pi lw$$

Rectangular entrance of length l and width w

$$A = lw$$

Parallelogram-shaped entrance of length l and width w

$$A = lw$$



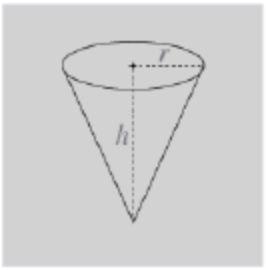
Note: The cross-sectional area of a vertical or subvertical entrance (e.g., a shaft or grike) is visually measured at the horizontal plane formed by the highest closed contour.

Figure 03. Cross-sectional area of cave entrances with vertical or sub-vertical aspect.

Right circular funnel of radius r and depth h

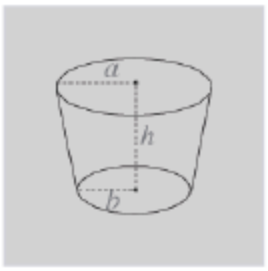
$$\text{Volume} = 1/3Ah$$

$$\text{where } A = \pi r^2$$



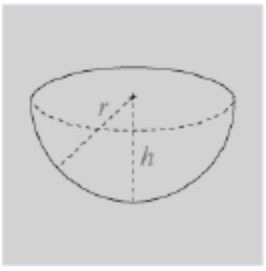
Frustrum of right circular funnel of radii a, b and depth h

$$\text{Volume} = 1/3\pi h(a^2 + ab + b^2)$$



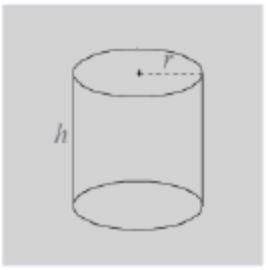
Spherical bowl of radius r and depth h

$$\text{Volume} = 1/3\pi h^2(3r\text{-}h)$$



Right circular cylinder of radius r and depth h

$$\text{Volume} = 2\pi rh$$



Circular cylinder of radius r and slant height L

$$\text{Volume} = \pi r^2 h = \pi r^2 L\sin\theta$$

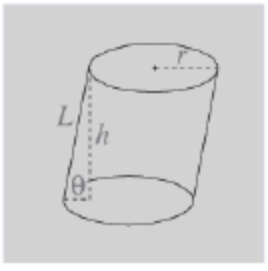


Figure D4: Geometry and volume of depression features.

APPENDIX 5 – Delineating Cave Infiltration Areas

Typically, the delineation of cave infiltration areas (CIAs) can only be completed if a cave map (survey) and/or profile is available. This is done as an office exercise whereby the plan outline of the cave is firstly transferred onto the cutblock map. The next stage is to determine the location of the surface infiltration area associated with the cave (or in some cases parts of a cave or cave segment). The cave infiltration area is projected to the surface using a 45° angle from the outside walls of the cave passage. The simplest way is to determine the depth of the cave opening from the cave profile, and then use this measurement to estimate the boundaries of the infiltration area in plan view[18]. For example, if the depth of a cave passage is 10 m and the infiltration area extends upward at an angle of 45° on either side of the cave passage, the limits of the cave infiltration area are located 10 m in horizontal distance from either side of the cave passage in plan view. In practice, it is suggested a conservative approach to these measurements is suggested as the actual infiltration area might be greater than the suggested 45°angle, particularly if there are any sinking streams or watercourses are present.

Two types of caves (cave segments) are considered for the purposes of Karst RSM of CIAs and are linked to how reserves are established above significant caves in the *Karst Management Handbook for British Columbia* (BC Ministry of Forests, 2003). In many cases, the significance of caves has not been determined, so the safest assumption is to assume they are significant until otherwise determined.

Type 1 caves (or cave segments) are identified as being located <10 m below the surface and should have suitable treed reserves and associated management areas to protect the cave infiltration areas. (whether known to be significant or not?)

Type 2 are identified as being >10 m below the surface, but are known to contain exceptional features (so they would be known to be significant). These require specialized practices within the cave infiltration area (e.g., partial cutting, full suspension yarding to minimize soil disturbance, and leaving of coarse woody debris and non-merchantable vegetation in place).

For a cave with Type 1 and Type 2 segments, both can be shown on the Karst RSM field map along with the respective cave infiltration areas. If information on the cave is lacking, assume the cave segments are Type 1.

If a cave is encountered and no associated cave map or survey is available, it maybe still be possible with some experience to make a judgmental best-guess on the likely extent of the first segments of a cave, based on knowledge of the karst unit boundaries and the surrounding karst landscape.

However, in most cases, this can be problematic and is obviously best done with a cave map or survey.

Once the cave infiltration area has been determined and located on a map, it is then possible to assess the presence/absence of forest cover or a designated retention area. Disturbances to the cave infiltration area can also be evaluated.

Reference

BC Ministry of Forests, 2003, Karst management handbook for British Columbia: British Columbia Ministry of Forests, Research Branch, Victoria, BC, 81 p., Available at: http://www.for.gov.bc.ca/hfp/publications/00189/Karst-Mgmt-Handbook-web.pdf

[18] The cave depth and horizontal distance relationship is based on simple trigonometry whereby tan 45°= depth of cave opening in cave profile/horizontal distance to edge of cave infiltration area in plan view.