These are answers by Jim Baichtal to questions to him from the Tongass Advisory Committee, November 2014.

Standards & Guides Karst Questions for Jim Baichtal

Q. What is the significance of karst?

Karst is a comprehensive term that applies to the unique topography, surface and subsurface drainage systems, and landforms that develop by the action of water on soluble rock (primarily limestone and marble (carbonates) in Southeast Alaska). The dissolution of the rock results in the development of internal drainage, producing sinking streams (streams that sink into the stream bed or karst features), closed depressions, sinkholes, collapsed channels, micro relief karst features (e.g. karren), and caves.

The geology and climate of Southeast Alaska are particularly favorable for karst development. Extensive areas of very pure carbonate (>95% $CaCO_3$), approximately 537,588 acres (840 square miles), are found within the boundaries of the Tongass National Forest. This includes carbonate bedrock on private, State, and Federal lands. Because of fractures in the carbonates, high annual precipitation, and peatlands adjacent to the carbonate bedrock, karst has developed, to varying extent, within all carbonate blocks. The Tongass National Forest contains the largest known concentration of solution caves in Alaska.

In Southeast Alaska the karst landscape can be characterized as an ecological unit found atop carbonate bedrock in which karst features and drainage systems have developed as a result of differential solution by surface and groundwaters. These acidic waters are a direct product of abundant precipitation and passage of these waters through the organic-rich forest soil and the adjacent peatlands. Recharge areas may be on carbonate or adjacent non-carbonate substrate. A few characteristics of this ecological unit include: mature, well developed spruce and hemlock forests along valley floors and lower slopes, increased productivity for plant and animal communities, extremely productive aquatic communities, well-developed subsurface drainage, and the underlying unique cave resources (Baichtal and Swanston, 1996, Wissmar et al., 1997, Bryant et al., 1998).

These karst areas are most comparable to those of karst lands found on Vancouver Island and the Queen Charlotte Islands of British Columbia, Canada, portions of Patagonia (Chile), Tasmania, and the west coast of the South Island of New Zealand. All of these areas have very steep surface slopes and subsurface hydraulic gradients, and very high levels of rainfall. These characteristics put them among the most dynamic karst terrains on earth, evolving and changing more rapidly and abruptly than karst in more moderate settings. The Karst Panel Report (Aley et al, 1993) found the karst lands of the Tongass to be of national and international significance for a variety of reasons. The Karst Review Panel in the summer of 2002 re-confirmed these findings (Griffiths et al., 2002). Both of these Panels consisted of world-renowned karst experts with a breadth of karst resource backgrounds and a wide variety of international exposure to karst areas and management considerations. Not only is the level of karst development and the karst hydrology and mineralogy globally significant, the paleontological and archaeological discoveries have, for the first time, written the prehistory of Southeastern Alaska and contributed to and challenged theories of the peopling of North

America. This research in conjunction with associated and ongoing palynology and glacial history research is defining the paleoecology of the region.

The natives and local inhabitants of Southeast Alaska have long known of the presence of caves. The existence of well-developed cave systems was first formally reported in 1975 and mapping of the caves began in 1987. The existence of vast areas in which karst had developed was fully recognized in 1990. Though noted by early foresters and geologists, about this same time the interrelationship between timber production and highly productive forests atop the karst landscape became apparent. With the passing of the Federal Cave Resources Protection Act (FCRPA) in 1988, the Forest struggled with methods to protect the many caves throughout the landscape. At first, protection focused on only the large, significant karst features and cave entrances. Subsequent measures tended to look at entire karst hydrologic systems including contributing non-carbonate catchments. These measures were limited by the need to provide timber for the long-term timber sale contracts that supplied the pulp mills and wood-products industry in southeastern Alaska.

The major focus and intent of the Tongass National Forest karst management strategy is to identify and protect karst systems and the caves and associated resources contained within, as per the requirements of the Federal Cave Resources Protection Act of 1988 (FCRPA). The FCRPA is the primary U.S. law affecting caves. It requires protection of significant caves on Federal lands. A cave must possess one or more of the criteria outlined in 36 CFR Part 290.3 to be determined "significant". Though "non-significant" caves may exist on the Forest, most meet the criteria for "significant". The intent of this act is to protect cave resources not karst resources. However, it is important to recognize that caves and associated features and resources are an integral part of the karst landscape. Karst must be managed as an ecological unit to ensure protection of the associated cave resources. In practice, the Forest gives equal protection to important karst features, sinking or losing streams, springs, and caves.

Q. What makes it so vulnerable to ground based activities such as timber harvesting?

The key factor of a particular karst system's vulnerability is that system's openness. The degree to which the surface is connected to the karst system conduits at depth relates directly to the effect of any planned land use. How open the system is gives insight to how quickly changes in hydrology, sediment and debris transport, and pollutants can affect the karst systems, the cave environments, and the surface resources they affect. In Southeastern Alaska, often the openness of the system is a function of that system's glacial history, the thickness and distribution of the glacial sediments, and that systems position on the landscape. A high density of solution and collapse features expressed at the surface indicates the presence of well-developed underground karst systems and surface connections. A low density of solution and collapse features indicate that either karst development is limited in some way or that it has been modified by glaciation and/or buried by glacial deposits. Under such areas however, karst systems and processes may be functioning at depth. Basing a management strategy on the systems openness makes that strategy applicable across many different occurrences, landscapes, and environments. Often the effects are not where the surface disturbance occurred it is at the spring feeding the anadromous stream over a mile away in under 24 hours.

Q. The current forest plan identifies 3 Karst classifications (High, Medium, and Low Vulnerability). Please explain the significance of these 3 classifications. What forest management activities does the current plan allow and/or prohibit in each of these classifications?

Assessing the vulnerability of the karst is a four-step process; Identify Potential Karstlands, Inventory the Karst resources, Delineate Karst Hydrologic System and Catchment Area, and Assess Vulnerability of Karst Terrain to Management Activity.

The final step is to delineate the land under investigation into various vulnerability categories. An area's vulnerability rating must be sensitive to potential surface management practices based on the extent to which epikarst has developed and the openness of the karst system. Where recharge is diffuse through deep soils the underlying karst is less vulnerable to increased sediment inputs and other pollutants than in areas where recharge is discrete and soils are thin or nearly absent. Where soils are thin or nearly absent surface disturbances will almost always result in exposure of the epikarst, providing an easy pathway for sediment and other pollutants to enter the subsurface drainage network. Discrete recharge areas are especially vulnerable to ground disturbing activities because the flowing surface water can carry sediment and other pollutants directly to the subsurface drainage network. Karst vulnerability mapping recognizes the variability in karst terrain and uses the vulnerability concepts described here to assign a high, medium or low vulnerability rating to an area of karst terrain. The proposed ground disturbing activity is considered when determining mitigation or applying karst management guidelines. The vulnerability categories and their criteria are as follows:

1. Low Vulnerability Karstlands

a) Classification Criteria. Low vulnerability karst lands are those areas where resource damage threats associated with land management activities in the areas are not likely to be appreciably greater than those posed by similar activities on non-carbonate substrate. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock which are moderately-well to well drained, most commonly internally drained but surface streams may be present. Generally, these areas have been greatly modified by glaciation, and a deep (>40" deep) covering of glacial till or mineral soil, and little or no epikarst showing at the surface. The epikarst may be buried and/or ground off, depending on the intensity of glaciation. These lands pose little or no threat to organic, sediment, debris, or pollutant introduction into the karst hydrologic systems beneath through diffuse recharge. Often these are areas of little or no slope (<20%). These tend to be at lower elevations, i.e. <500 feet, however the elevation of low vulnerability karst will vary across the Forest.

b.) Low Vulnerability Karst Management Objectives and Appropriate Land Uses - These are areas where no special provision for the protection of karst values is considered necessary. Timber harvest and related activities could be conducted in such areas in a similar manner to those normally employed on lands underlain by non-carbonate bedrock. Partial suspension yarding may be required. No quarry shall be developed atop karst without adequate site survey and design. Quarries should be properly closed after abandonment. Recreational development would be appropriate with consideration of karst resource values. It is possible that karst areas with high vulnerability will be found within and adjacent to areas found to be of low vulnerability. Along such boundaries or margins, guidelines for protecting these high vulnerability areas outlined under "Moderate Vulnerability Karst lands" (3.D. b. ii. (a)-(c)) shall apply.

2. Moderate Vulnerability Karstlands.

a) Classification Criteria. The moderate vulnerability karst lands are those areas where resource damage threats associated with land management activities in the areas are appreciably greater than those posed by similar activities on low vulnerability karst lands. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock that are well drained internally. Surface streams are rare. The soils of moderate vulnerability areas are a mosaic of shallow organic (20-40%, McGilvery Soils) and mineral (80-60%, Sarkar [<20" depth] and Ulloa [> 20" depth] Soils) with minor amounts of glacial till. The epikarst is moderate- to well-developed and is visible at the surface. These areas tend to be at higher elevations, i.e. >500 feet, and on knobs, ridges, and on the dip-slope of carbonate bedding planes when near the surface. The surface of these areas tends to be irregular and undulating, following the epikarst development which is the result of solution of the bedrock surface rather than solution and/or collapse features such as sinkholes. In other words, moderate vulnerability features are often the result of slow, diffuse processes rather than collapse or major subsidence processes, which typify high vulnerability features. Moderate vulnerability karst lands pose low risk to organics, sediment, and debris introduction into the karst hydrologic systems beneath. It is probable, but not always the case, that these areas contain or are adjacent to areas of high vulnerability.

Much difficulty lies in differentiating between the high end of the moderate vulnerability karst, and the low end of the high vulnerability karst. In using a classification system there is rarely an exact fit to the environment or specific area being investigated. As stated above, classification is dependent upon extent of karst development and openness of the system. This can be difficult when surrounded by an environment with no surface water streams, and limited exposure to the development of the underground system, as is often the case in these 'gray areas' between moderate and high vulnerability karst. Aside from the level of development and the openness of the system, the density of both karst features and exposed epikarst can be used when classifying the vulnerability of an area. A high density of features and/or very –well developed epikarst in a 'gray area' would result in a high vulnerability classification whereas a few minor features and moderate epikarst development with soil retained might be classified as a moderate vulnerability area. It is crucial to evaluate the immediate area as well as the surrounding environment and any contributing characteristics when using this vulnerability system.

b.) Moderate Vulnerability Karst Management Objectives and Appropriate Land Uses - Management objectives on these lands is to provide for other land uses while taking into account function and biological significance of the karst and cave resources within the landscape. Timber harvest and related activities could be conducted in such areas under more restrictive guidelines than normally employed on lands underlain by non-carbonate bedrock. To protect the fragile soils found here, as a minimum, the yarding system selected may be required to achieve partial suspension. Longer timber harvest rotational periods may be appropriate. Reduced timber harvest unit size and a greater dispersal of harvest units may be required.

1. Road Construction. Existing roads will be utilized in preference to the construction of new ones. Roads should avoid sinkholes and other collapse features and sinking or losing streams. Roads should not divert water to or from karst features. Measures shall be taken to reduce erosion and sediment transport from the road surface and cut slopes. Assess the need for ditches and culverts. Sediment traps, cut and fill slope revegetation, and road closure and revegetation may be appropriate. Because subsurface drainage networks may be more open to the surface in moderate vulnerability areas, additional design criteria may be required. Such criteria may relate to road construction methods, blasting, culvert placement and density, and sediment retention and erosion prevention. Road construction restrictions described below under "high-vulnerability prescriptions" may be required for these areas.

2. Quarries. Existing quarries will be utilized in preference to the construction of new ones. No quarry shall be developed atop karst without adequate site survey and design. Quarries should be properly closed after abandonment. Recreational development would be appropriate with consideration of the karst resource values listed above, particularly with respect to reducing disturbance of sensitive soils and use of construction methods that avoid erosion and diversion of natural and road drainage waters into karst features.

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3. Karst Feature Buffers It is probable that individual features or areas with high vulnerability will be found within and adjacent to areas found to be of moderate vulnerability. Along such boundaries or margins the following guidelines shall apply:

i. No surface disturbing activity such as timber harvest, road construction, and/or quarry development shall occur within a minimum of 100 feet of the edge of a cave, sinkhole, collapse channel, doline field, or other collapse karst feature. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness (RAW) of that zone (pay special attention to the area within two site-potential tree heights of the no-harvest zone). The intent of the buffers surrounding karst features is to minimize the amount of woody debris and sediment entering a given karst system and to maintain, to the extent practical, the natural processes and environment surrounding those features. It is not intended that this level of protection would be applied for relatively minor, isolated features (i.e., where explicit or special management measures would not normally be required). Appropriate protection measures for minor features should be designed on a case-by-case basis as field assessed by a karst management specialist. When designing buffers to protect karst systems and their features, the buffer should be designed to be wind-firm. There is no credible standard buffer distance that will provide the assurance required to protect the systems from blow down of the forest within a given buffer. Each buffer must be carefully designed considering wind direction, blow down history, previous adjacent harvest, topography, and stand windfirmness. Delineated lands surrounding such features and systems must be of sufficient size to insure protection even if blow down occurs. It is suggested that the specific design of the buffers be an IDT recommendation working with the karst management specialist during the planning process for any given project. Not all features will require the RAW buffer considering the specific characteristics of each.

ii. No surface disturbing activity such as timber harvest, road construction, and/or quarry development will occur on lands that overlie a known "significant" cave. "Overlie" is defined here as the area between lines projected from the outside walls of the cave passage at a 45-degree angle to the surface. In practice, lands that "overlie" a significant cave should be classed as high vulnerability even if other characteristics would suggest a lower rating. As suggested above, the specific design of the buffers should be an IDT recommendation working with the karst management specialist during the planning process for any given project.

iii. As cave discoveries are made and those caves are mapped and inventoried, it is quite probable that very significant cave systems will be discovered. These might contain significant paleontological, cultural, or biologic resources or the system is of a particular size to warrant an extra level of protection. Cave systems such as El Capitan Cave on Prince of Wales Island, Arabica and associated caves on Heceta Island, Solstice Cave on Chichagof Island, and the

Calamity Creek Caves on Revillagigedo, Island are examples. It is suggested that on a case-by-case basis for such caves, a Geologic Special Area be defined and managed as such to protect these systems.

iv. Require protection of all sinking or losing streams and their tributaries irrespective of whether the channels carry perennial, ephemeral, or intermittent flows. A non-harvest buffer is required of a minimum of 100 feet from the edge of a sinking or losing stream within no less than ¼ mile (1320 feet) upstream of their swallow hole or loss point. Additional protection beyond this point many be needed and should take into consideration parameters such as gradient, channel type, soil characteristics, and susceptibility to mass wasting and erosion along the stream's or tributary's course or within the watershed. The karst management specialist should work in conjunction with hydrologists and soil scientists to design additional stream protection if needed. Manage an appropriate distance beyond the no-harvest zone to provide for a reasonable assurance of windfirmness of that zone (pay special attention to the area within two site-potential tree height of the no-harvest zone. In the event that the stream is less than 1/4 mile long, the stream will be buffered to the stream's source.

v. The area surrounding resurgences should be protected to maintain the environment surrounding the springs and the quality of the waters flowing from them. Resurgences can however be classified as moderate or high vulnerability dependent upon their size, the habitat they provide, and the level of atmospheric connectivity between the resurgence and the underground karst system. Minor resurgences which seep out of the ground between gravels with almost no connectivity between the open atmosphere and the underground system will be classified moderate vulnerability. Appropriate protection measures for moderate vulnerability resurgences and springs should be designed on a case-by-case basis by a karst management specialist. All other resurgences will be classified as high vulnerability and protected as described in Karst Feature Buffers (III., D., b., ii., C., 1) above Special consideration should be given to the area immediately surrounding the springs to protect the flora and fauna often associated with the spring when considering the vulnerability.

3. High Vulnerability Karstlands

a.) Classification Criteria. The high vulnerability karst lands are those areas where resource damage threats associated with land management activities are appreciably greater than those posed by similar activities on low or moderate vulnerability karst lands. These are the areas contributing to or overlying significant caves and areas containing a high density of karst features. The following is a generalized characterization of these lands:

These are areas underlain by carbonate bedrock that are well drained internally. Surface streams are rare. Karst systems and epikarst are extremely well developed and collapsed karst features may be numerous. These include all collapsed karst features, caves, sinking or losing streams, insurgences, open resurgences, and open grikelands (i.e., those without soil or moss infilling and with open connections to the subsurface). The highest vulnerability features are those that could produce and transport the greatest amount of sediment, debris, and/or organics if disturbed. These include till-lined sinkholes and cave entrances accepting a sinking stream, whether intermittent or not. Also considered high vulnerability are karstlands in which the epikarst is well- or extremely well-developed and the soils are predominately (>50%) very shallow organic (<10"deep, McGilvery), and (<50% mineral (<20" deep, Sarkar). The subsurface drainage network is highly vulnerable to sediment, organic matter, logging debris, and other pollutants generated as the result of surface activities.

b.) Karst Management Objectives and Appropriate Land Uses. These areas shall be managed to insure conservation of karst values through the implementation of a high level of protection. Timber management and related activities should be excluded from these lands. Small expanses of these areas may be crossed by roads to access areas where harvest is appropriate, i.e. low or moderate vulnerability karst lands and non carbonate areas. This would only be allowed if no other route or option was available and karst resource values would not be compromised. If roads must be built across areas of high vulnerability the following design and construction may be appropriate:

i. Minimize clearing limits and grubbing. Flush cut stumps to the ground. Do not deck logs pioneered from the road clearing limits outside the clearing limits.

ii. Use a fill-type construction rather than a balanced cut and fill design. This most likely will be possible since the slope gradient of these areas are generally >15%.

iii. Utilize log stringer bridges or similar structures to span across collapse features if necessary. Geotextile should be used to keep aggregate overlay from falling into the collapse feature.

iv. Sediment traps and erosion control measures will be needed in most cases.

v. Same-season re-vegetation of the cut and fill slopes should be required to minimize sediment production potential.

vi. A "plan-in-hand" review by the karst management specialist of the proposed road construction prior to actual construction is required.

vii. The karst management specialist needs to work closely with engineering to carefully design these roads coordinating efforts with the planning team.

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viii. No quarry development would be allowed on these lands. Limited recreational development may be appropriate. Roads across such sensitive terrain except as described above, are inappropriate. Recreational facilities and trails would have to consider karst resource values and objectives discussed above, particularly with respect to reducing disturbance of significant epikarst features and sensitive soils and use of construction methods that avoid erosion and diversion of natural drainage waters into karst features. Karst lands found to be of high vulnerability shall be identified and removed from the commercial forest lands suitable land base.

Q. Should these 3 classifications and the associated allowed/prohibited activities be applied to young growth (YG) timber management and harvest as they are now applied to old growth; or is there a need or an opportunity for new YG specific criteria and activities?

The karst vulnerability assessment should be applied to YG stands and the prescriptions for their management designed to consider the function of the karst sytems.

Q. Given the productivity of karst, the fact that a lot of the older and more valuable YG is located on karst, and the fact that theTongass NF is transitioning to YG; can you offer some recommendations (e.g. prescriptions, harvesting methods, equipment, adaptive management, etc.) that may provide YG management opportunities and/or flexibility in and around karst areas?

Young growth management on Karst

A. On lands underlain by carbonate, where either pre-commercial or commercial thinning is proposed, a karst resource inventory shall be conducted as described in Appendix H. The openness of the underlying karst system, that system's vulnerability to surface disturbance, and the likelihood of additional sediment production or runoff by thinning the young-growth timber shall be determined.

B. Pre-commercial thinning is appropriate on all karst lands when the karst management objectives can be met. Pre-commercial thinning to near the edge of karst features or the bank of sinking or losing streams is allowed; however, no slash or debris may fall or be placed in these features. It is probable that a zone equal to one tree height be left untreated to ensure that no slash or debris will be placed in these features. If any introduced slash or debris finds its way into karst features or losing streams, it must be removed by hand. Commercial thinning is appropriate on low to moderate vulnerability karst lands when the karst management objectives can be met. Generally, no thinning shall be permitted on lands determined to be of high vulnerability such as within 100 feet of a cave entrance, a karst feature accepting surface flow, or of the edge of a sinking or losing stream within 0.25 mile upstream of their swallow hole or loss point.

C. On a case-by-case basis, other karst features will be assessed as to their susceptibility to surface disturbing activities, the proposed harvest method, and the thinning prescription. The area surrounding these features is still considered high vulnerability and should be mapped as such; however, thinning of this sensitive area might be considered permissible. All features not fully protected would be buffered from their center to just outside the lip of the sink allowing for thinning within the area that would normally be a non-harvest buffer. It is probable that a zone equal to one tree height be left untreated to ensure that no material will be placed in these features. All thinned timber will be directionally felled from the untreated area surrounding the karst feature and split yarded from the area. Any material landing on the slope break of the feature or within the feature will be removed by the least invasive method available. No yarding across or through the untreated area surrounding the feature will be allowed. Directional falling and split yarding away from the karst depressions and features should provide adequate protection for water quality and karst features.

D. Within Geologic Special Areas designated because of karst development, management of young growth may be appropriate. Pre-commercial and commercial thinning shall be allowed when the karst management objectives can be met. Thinning of over-stocked stands would hasten a return to more desirable stand conditions on historically harvested sites. The management of the stand to closer-to-pre harvest tree stocking, canopy closure and canopy interception would be of benefit to the karst systems. The design of the thinning will be designed on a case-by-case basis.

From Ben Case…

	All Karst Acres	High Vulnerability Acres
Acres of Karst boundaries of the Tongass (all land ownership)	647,431	74,111
Acres of Karst on Tongass National Forest lands	459,027	73,672
Acres of Even-aged Harvest (2013) on Karst for all LUDS	93,137	6,320
Acres of Even-aged Harvest on Karst >55 in all luds	8,115	345
Acres of Even-aged Harvest, age >55yrs on Karst and otherwise 'suitable'	5,816	259