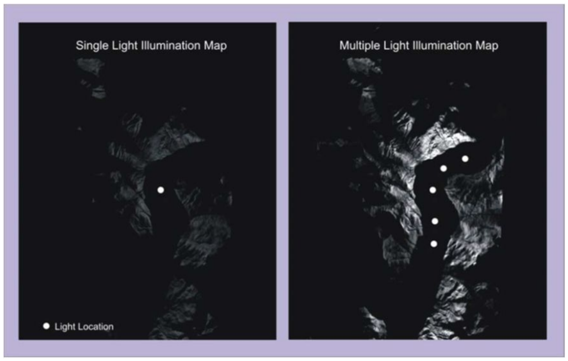
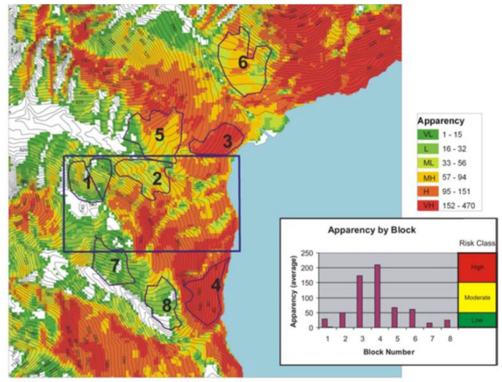
KB Fairhurst – GEOptics – PhD Dissertation -2010 – A Partial Distillation by KBF - 2021





A partial distillation of the PhD Dissertation by Kenneth Barton Fairhurst 2010 entitled GEOptics landscape apparency : a dynamic visual resource indicator and tool for multi-functional landscape planning. Faculty of Forestry, the University of British Columbia, Vancouver
prepared by Dr. K.B. Fairhurst, PhD, RPF, RDI Resource Design Inc, April 5, 2021
See or download the full dissertation at http://hdl.handle.net/2429/28006, UBC Library Vancouver.

Forest managers must consider visual quality objectives to meet public expectations for use and enjoyment of forest landscapes. These applications of visual constraints have been criticized for being overly restrictive, and for causing a lack of opportunity for appropriate development. At the same time, inadequate planning and design can cause unnecessary visual impacts in the landscape. Past studies of visual vulnerability, visual magnitude, and angle of visual incidence have attempted to identify relative risk of visual impact. A new approach was sought that might help alleviate those problems, and improve the ability to forecast, model, and manage that risk. Perspectival variability affects how the landscape is seen, and poses complex challenges in the planning and management of visual resources. Therefore, a dynamic and quantitative approach to landscape classification was developed to provide greater understanding and control from multiple viewpoints. A landscape illumination mapping technique in a three-dimensional terrain model was applied as an analog for viewing from multiple viewpoints. The intensity of illumination, termed cumulative landscape apparency, provided an indicator of relative risk of visual impact for each grid cell in the landscape model. The model was validated internally through tests and applications and externally through focus group testing. Apparency can provide a new, reliable, geographic information system-based inventory measure that will help guide resource planning, design, and integration. It has been shown to offer a potential enhancement to visual landscape inventory, and is expected to be useful to land managers without a strong background in visual resource management, by reducing their reliance on experts and increasing their success in meeting visual quality objectives relative to current planning methods. Apparency was shown to reveal inherent patterns in the landscape that would be useful for differentiating areas requiring greater and lesser attention, improving harvest design outcomes, and partially automating or guiding the design. The knowledge gained in testing apparency for its relation to plan-to-perspective analysis can potentially provide an indicator for refining resource supply questions. GEOptics is expected to be applicable to a wide array of visual resource management and resource planning mechanisms in BC and other jurisdictions.

Presented herein are a collection of key figures and tables which provide some understanding of the merits of GEOptics visual landscape apparency in relation to visual landscape inventory, meeting visual quality objectives, and long term and automated planning of visual resources.

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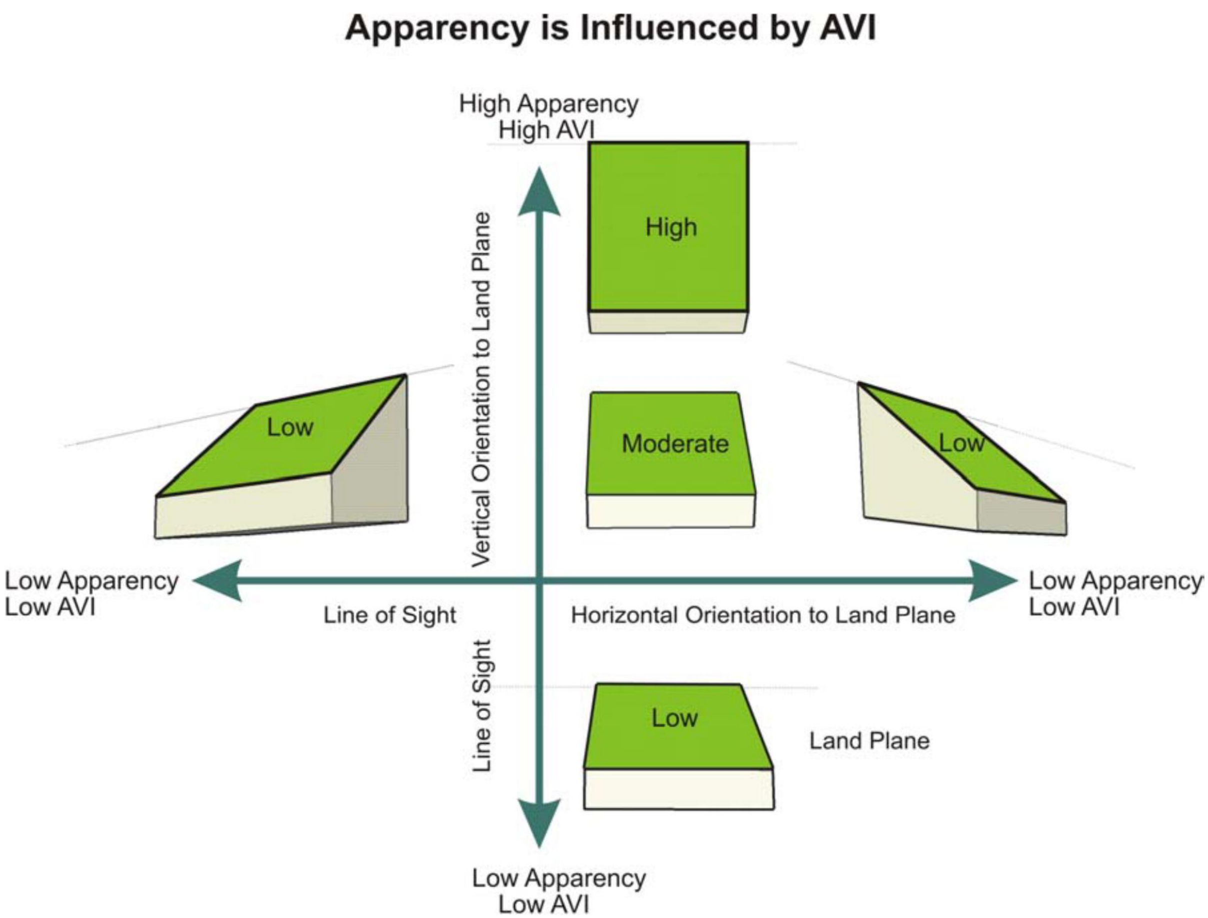


Fig. 1 Relationship between landscape apparency and angle of visual influence

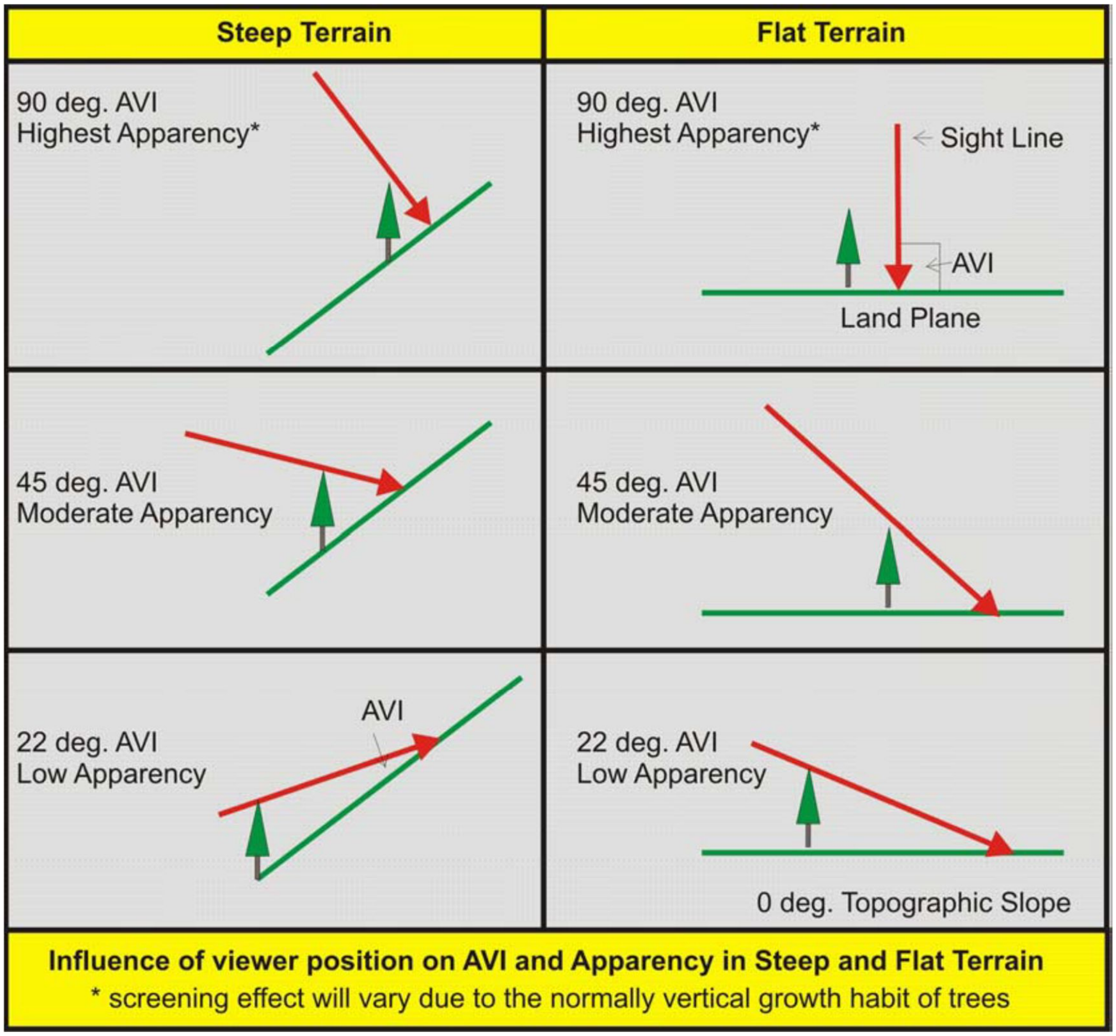


Figure 6 Influence of viewer position on angle of visual influence and apparency in steep and flat terrain

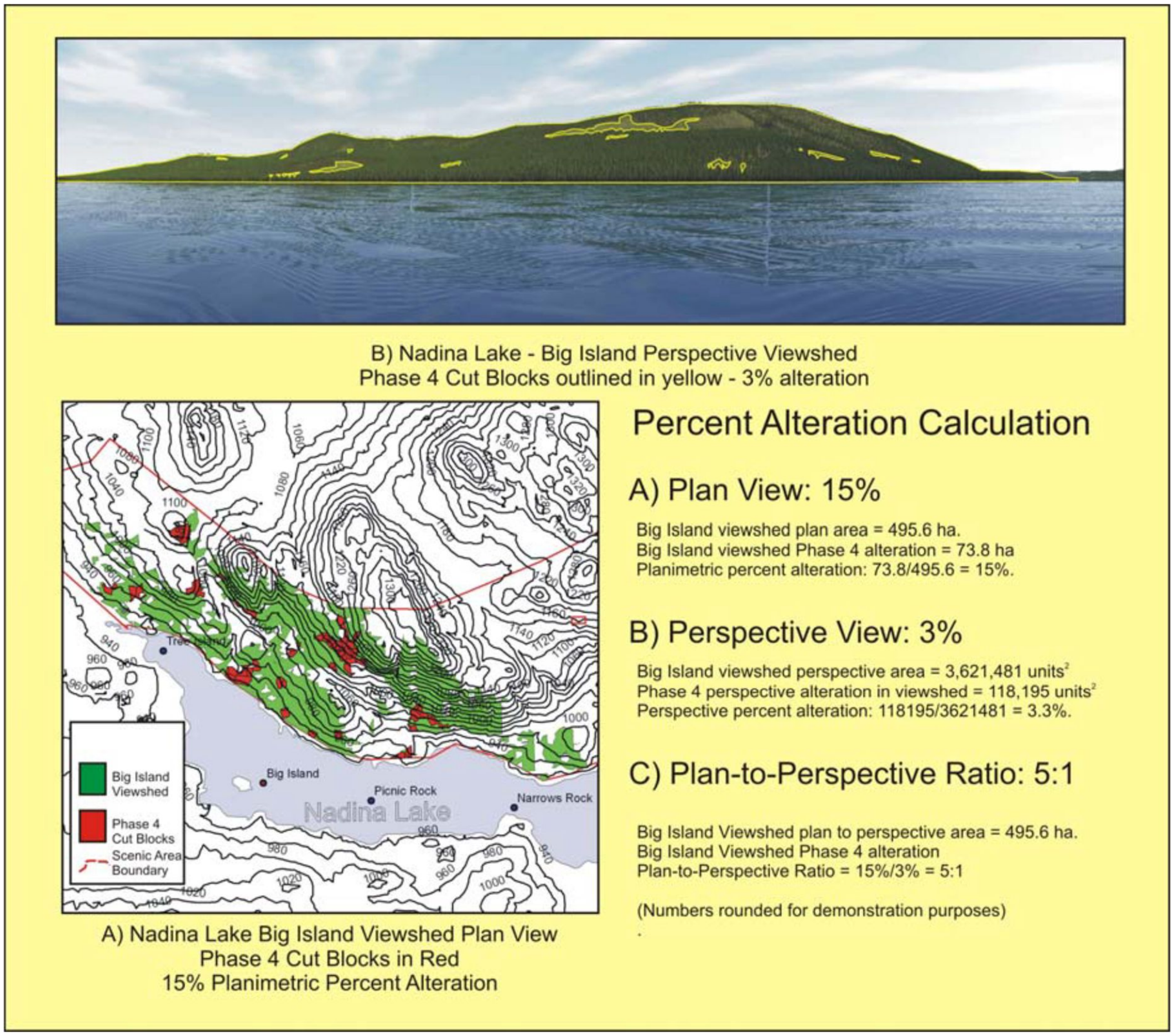


Figure 8 Percent alteration calculation method in plan view and perspective view with tree screening and the plan-to-perspective ratio derived from the two measures

Table 1 Predicted P2P ratios for slopes 0% - 70% for all visual designs (BCMoF 2003, Table 4).

Slope	0%	10%	20%	30%	40%	50%	60%	70%+
P2P	4.68	3.77	3.04	2.45	1.98	1.60	1.29	1.04

Table 6 Potential contribution of GEOptics apparency to Visual Resource Management Processes (using the BCMoFR VLM as an example). General VRM Category (Phase/Stage)

Process/system	Inventory	Analysis	Design
EVA/VRM systems (general)	Visual vulnerability, visual magnitude, visual thresholds; angle of visual incidence (AVI); VAC; Visual contrast rating.	Studies provide tests and measures; VRM systems set classes and objectives for VRM; usually with descriptive but not numerical constraints.	Provide design considerations and examples.
Current VLM (BCMoFR)	Visual vulnerability factors (VAC) VLM Phase 1: VLI.	VQOs: verbal/numerical constraints for visual quality (P2P weighting by slope class factor over landbase (VLM Phases 2-3).	VQOs guide planning, design, and operations. Numerical; new information acquired at this stage from additional viewpoints, visual simulation, visual impact assessment, integrated visual design (VLM Phase 4); leading to implementation (Phase 5) and effectiveness monitoring (Phase 6).
Potential Applications of GEOptics Apparency	Apparency rating as a potential visual vulnerability/risk/AVI factor derived from cumulative viewpoint analysis (GEOptics Stages 1-4, see Table 7)	Potential VQO Apparency Class as a numerical P2P weighting factor for each landbase as completed; potentially-entered in TSR (GEOptics Stage 5).	Apparency values potentially applied to guide design and operations; visual simulation and visual impact assessment; hierarchical integrated planning (GEOptics Stage 6).
GEOptics Research Questions	Research Question 1: Is apparency applicable to VLI/VLM?	Research Question 2: Can apparency improve planning?	Research Question 3: Can apparency improve design? Research Question 4: Can apparency improve integrative modelling?
Apparency Evaluation Criteria	1) Feasibility – how apparency works, quantifies, integrates; 2) Validity and Defensibility – internal and external reliability; precision, accuracy; objectivity; 3) Effectiveness – in comparison to, or contributing to current VRM system(s) and GIS tools; and, 4) Usability (by others).		

Table 7 GEOptics procedures, products and applications, by Stage and Research Question.

GEOptics Landscape Apparency						
Procedures, Products and Applications	**Inventory**				**Analysis**	**Design**
	Stage 1 Terrain	**Stage 2 Illumination**	**Stage 3 Classification**	**Stage 4 Integration**	**Stage 5 Analysis**	**Stage 6 Planning**
	Construct terrain DEMs.	Produce cumulative illumination / shadow maps as basis for apparency mapping.	Classify apparency map by RGB values, single light, cumulative lights; compare with raster viewshed, times-seen, and slope mapping.	Integrate apparency map with other resource databases, leading to further applications.	Percent alteration and plan-to-perspective calculations for apparency classes, for strategic planning applications.	Tactical and operational planning applications of apparency mapping.
Projects	Howe Sound project; Nadina IVDP.	Pre-tests: Stella Lake; Dishtin.	Howe Sound project; Nadina IVDP.	Howe Sound; Nadina IVDP.	Howe Sound; Nadina.	Nadina IVDP; Atlas-Nadina; Howe Sound.
Research Question	1. Does apparency improve Inventory?				2. Does apparency improve strategic planning?	3. Does apparency improve design? 4. Does Apparency improve tactical / operational planning?

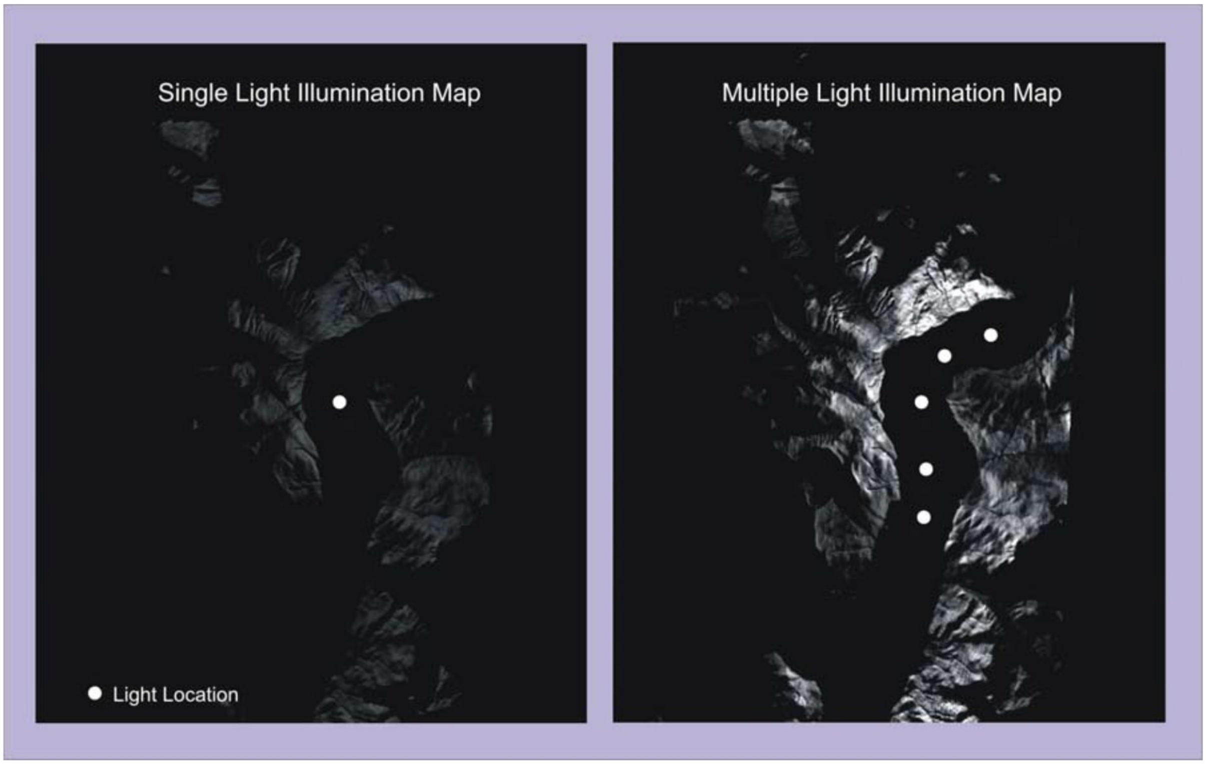


Figure 20 Examples of single light at LCP 120 (left image) and multiple light (right image) cumulative illumination maps, Howe Sound project produced with Visual Nature Studio.

The basis of GEOptics is the casting of light from viewpoints to illuminate each visible landplane of a landscape as the analog to human vision casting sight upon each land plane of the same landscape. Cumulative light intensity is an indicator of relative risk of visual impact for each grid cell in the landscape model. Visual Nature Studio was employed for light cast from each viewpoint. Examples of a single light illumination map and a multiple light map are presented for the Howe Sound project in Figure 20 (above). The image for the single light source (left image) is quite dark in appearance, while the multiple light image (right image) is much brighter, revealing the cumulative illumination apparency from five light sources. Face-on perpendicular land planes have 100% light intensity (bright white; RBG values 255, 255, 255); fully parallel planes and planes turned away from the sight line (i.e., no contact) have 0% intensity (black; RGB values 0, 0, 0); with gray-scales in between that represent 81 intermediate light intensities. There is, by necessity, no ambient light, nor is there any spectral reflectance, just diffuse reflectance. The capability of adding lights together to derive the cumulative effect, and to consider the viewpoint importance by changing light intensity, were tested for validity, accuracy and replicability. The illumination map is an improvement over topographic slope maps as indicators of relative risk of visual impact as illumination maps show not just what of the terrain is seen as in viewshed and times-seen mapping but how the terrain is seen, accounting for the angles of visual incidence from all viewpoints to each and every visible land-plane, mimicking the variety of viewing opportunities towards each land-plane. thus establishing a measure of visual risk or vulnerability to visual impact. The influence of tree screening also varies with viewer position and angle of visual incidence (AVI) (see Fig. 6).

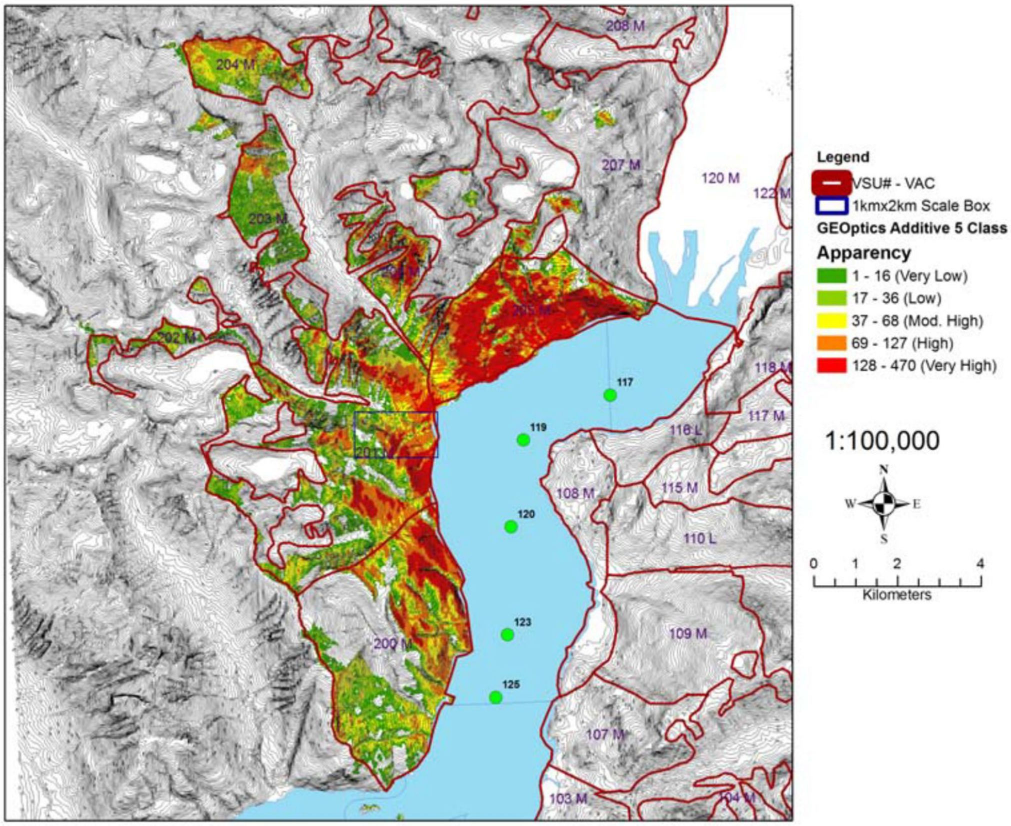


Figure 24 Howe Sound five quantile class additive cumulative apparency raster map produced from the addition of 5 individual illumination maps (additive method) from each viewpoint; VLI Visual Sensitivity Units added for reference.

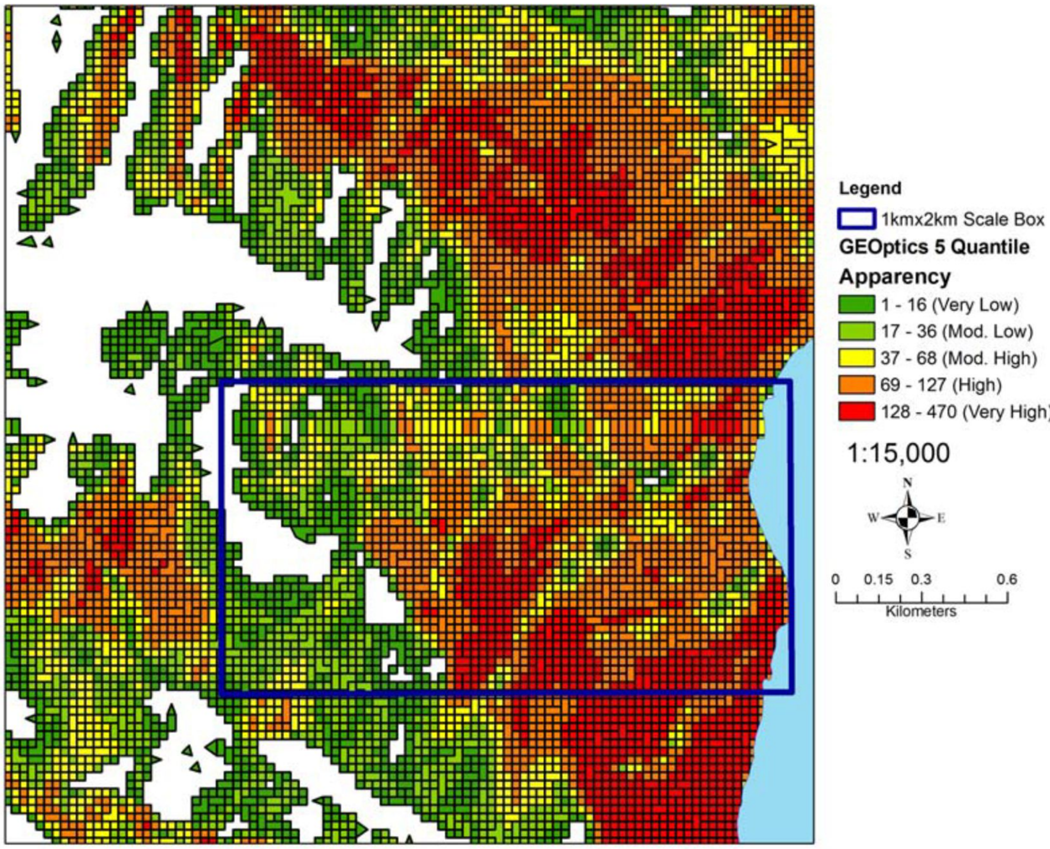


Figure 25 Polygonized apparency map derived by converting a raster GEOTIFF apparency map, with apparency values attached as attributes, classified by quantiles as with the GEOTIFFs. Automatic simplification of polygons (polygon merging) is evident within the scale box.

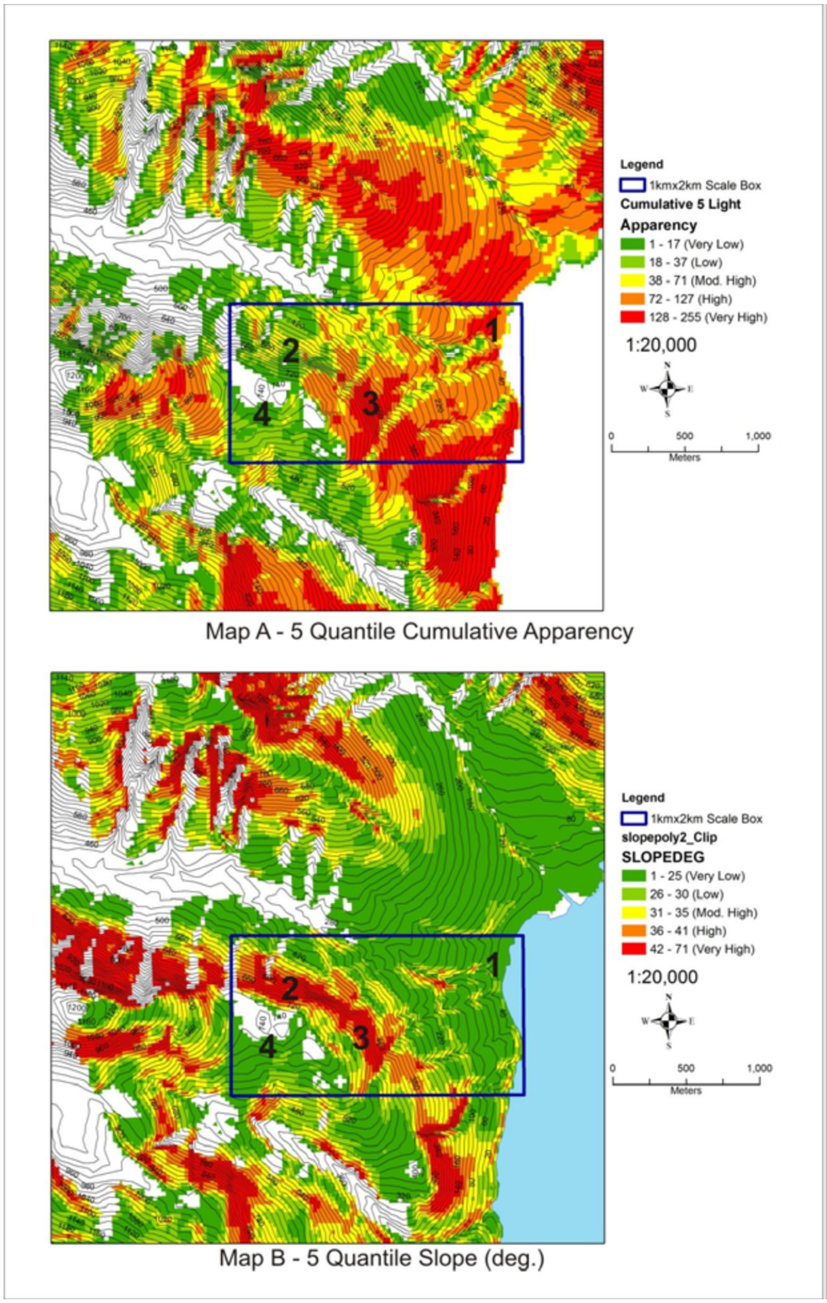


Figure 47 Comparison of 5 quantile cumulative apparency (Map A) and 5 quantile topographic slope (Map B); Howe Sound model close-up.

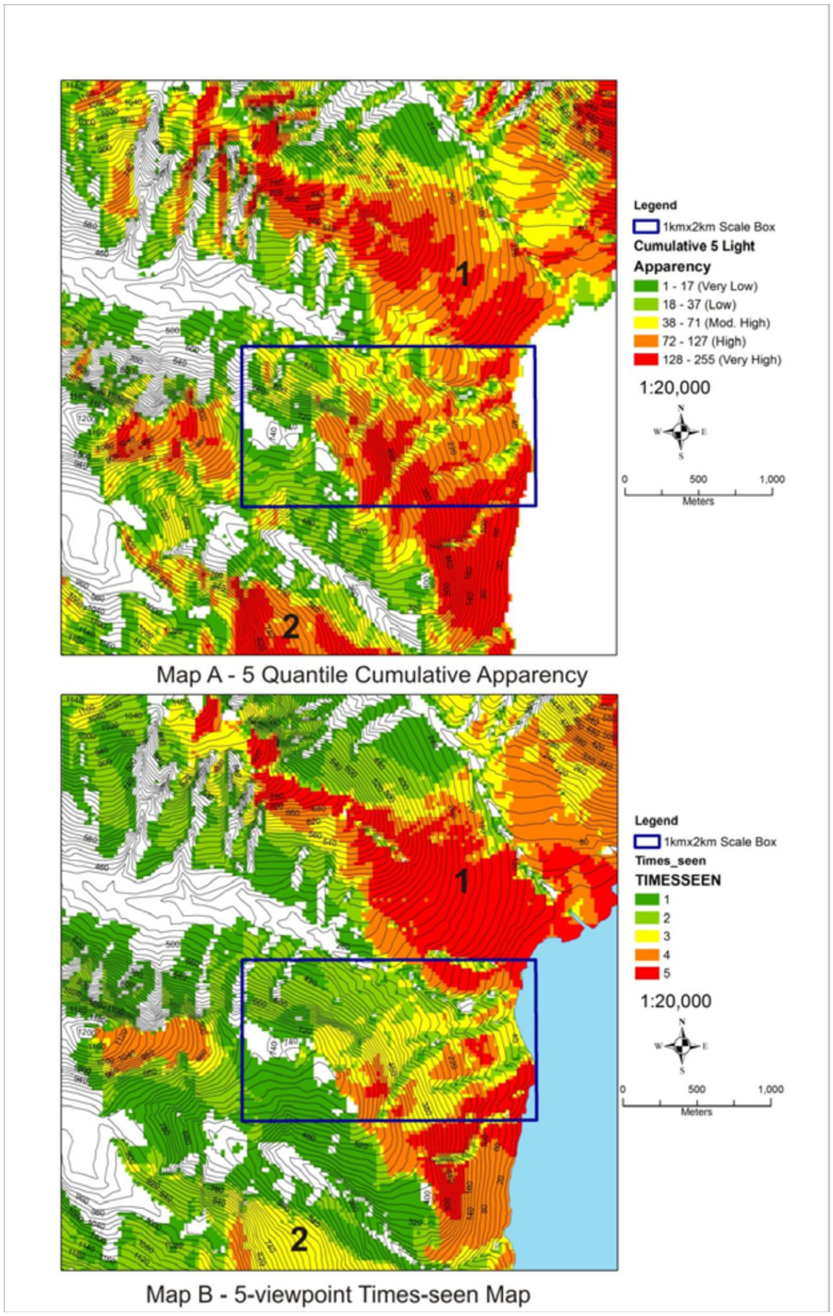
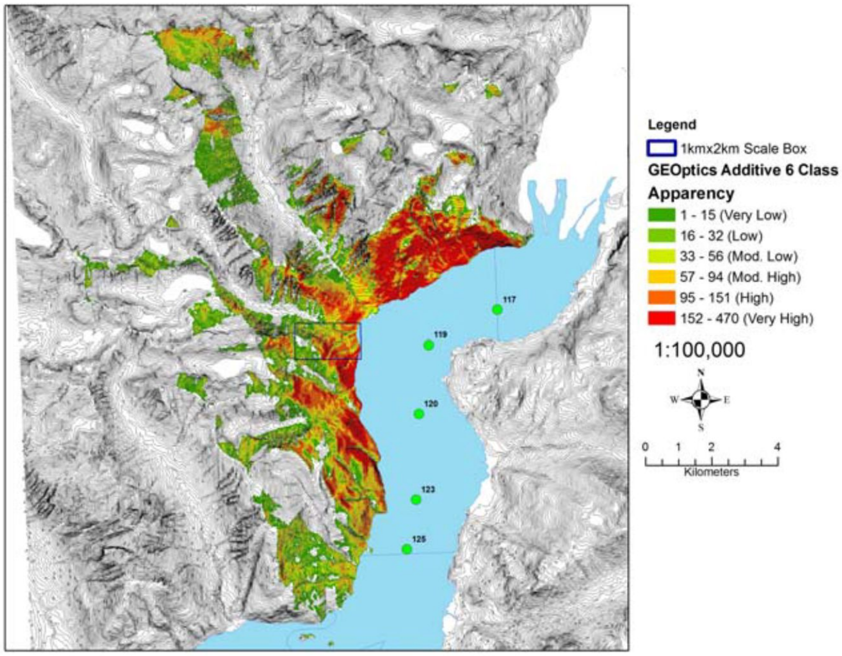


Figure 49 Close-up comparison of Howe Sound project cumulative apparency (Map A) and times-seen (Map B), indicating the finer differentiation of apparency mapping, classified into quantiles, with the same number of classes as times-seen from the same viewpoints.



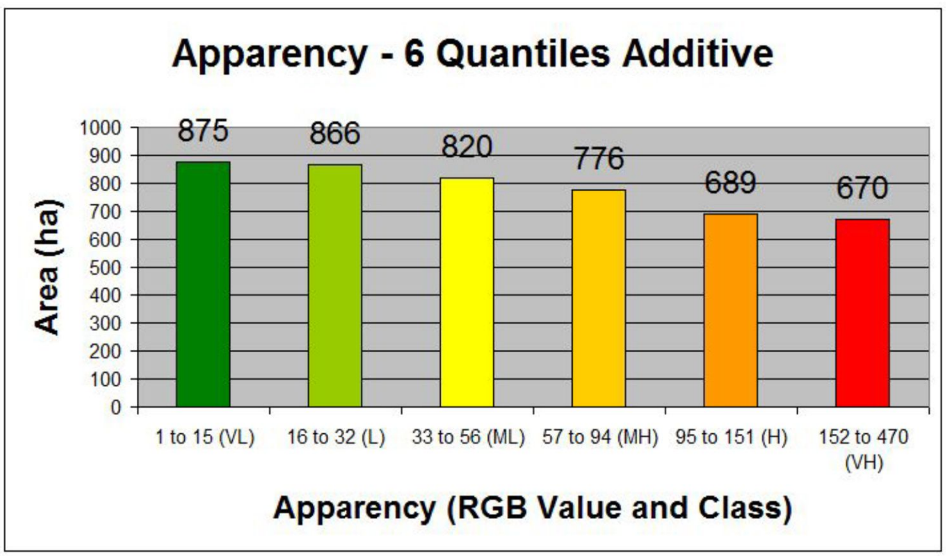


Figure 50 Polygonized, 6-quantile additive apparency map and quantile area histogram; Howe Sound.

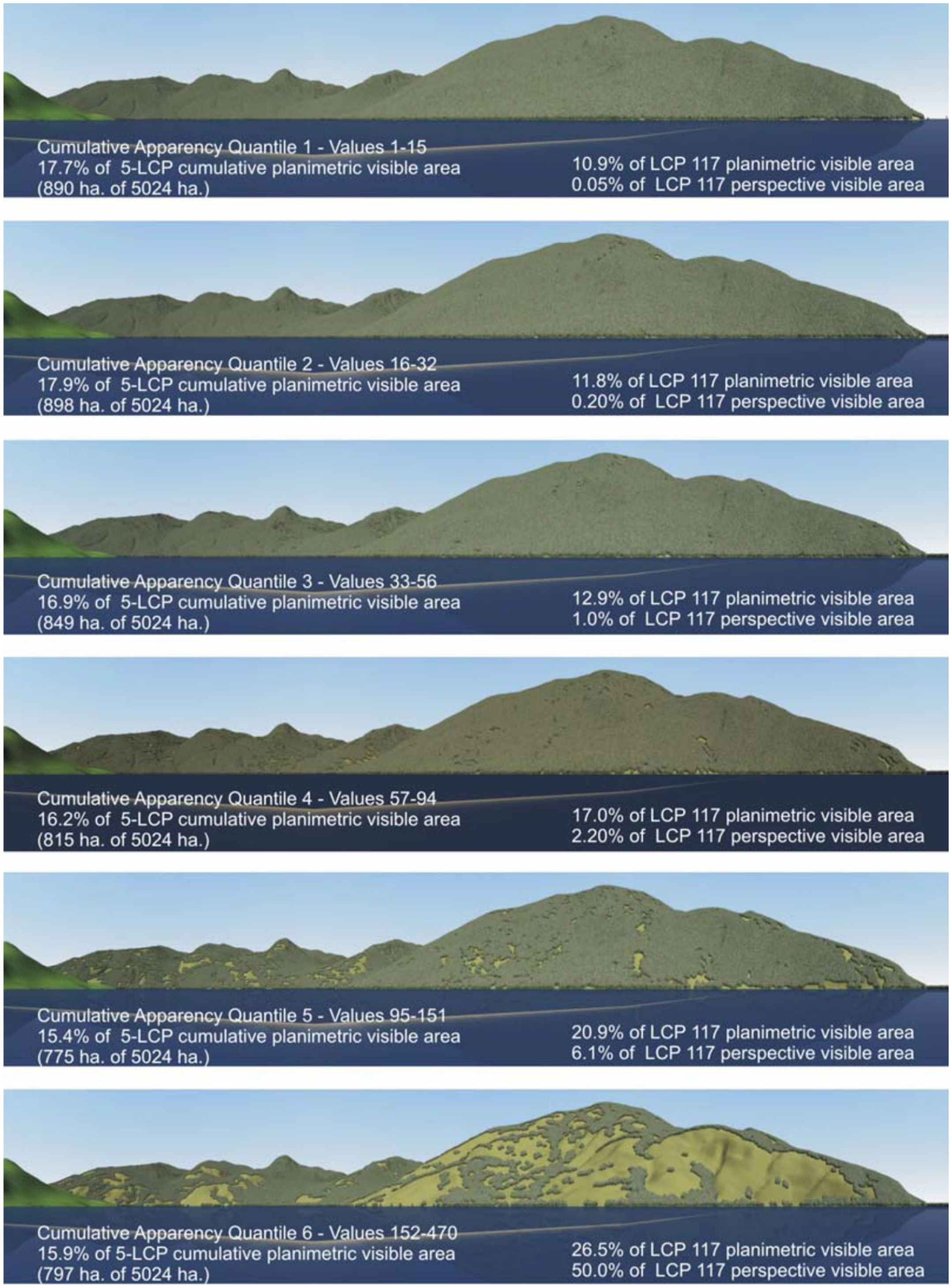


Figure 53 Cumulative apparency by quantile group – Howe Sound VNS forest model, LCP 117, depicting the amount of visible change that would be caused by individual quantile groups (tan colour) in the forested terrain, if harvested, with cumulative and LCP-specific planimetric apparency map area measures, and LCP-specific perspective measures; full-width view.

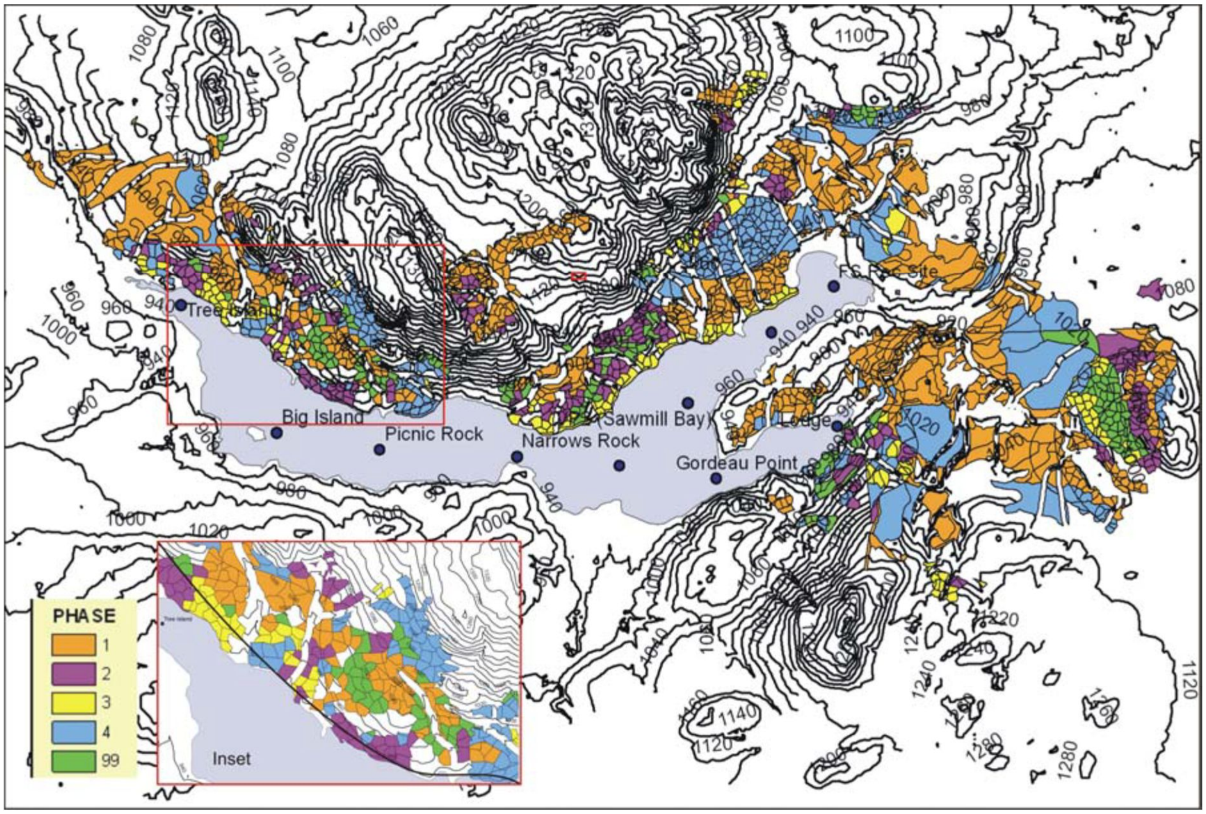


Figure 75 Nadina Lake 4 pass scheduling to meet VQOs applied to treatment units based on cumulative apparency and iterative testing with perspective visualizations, with inset showing closer view of treatment units; Class 99 units were not set to a schedule.

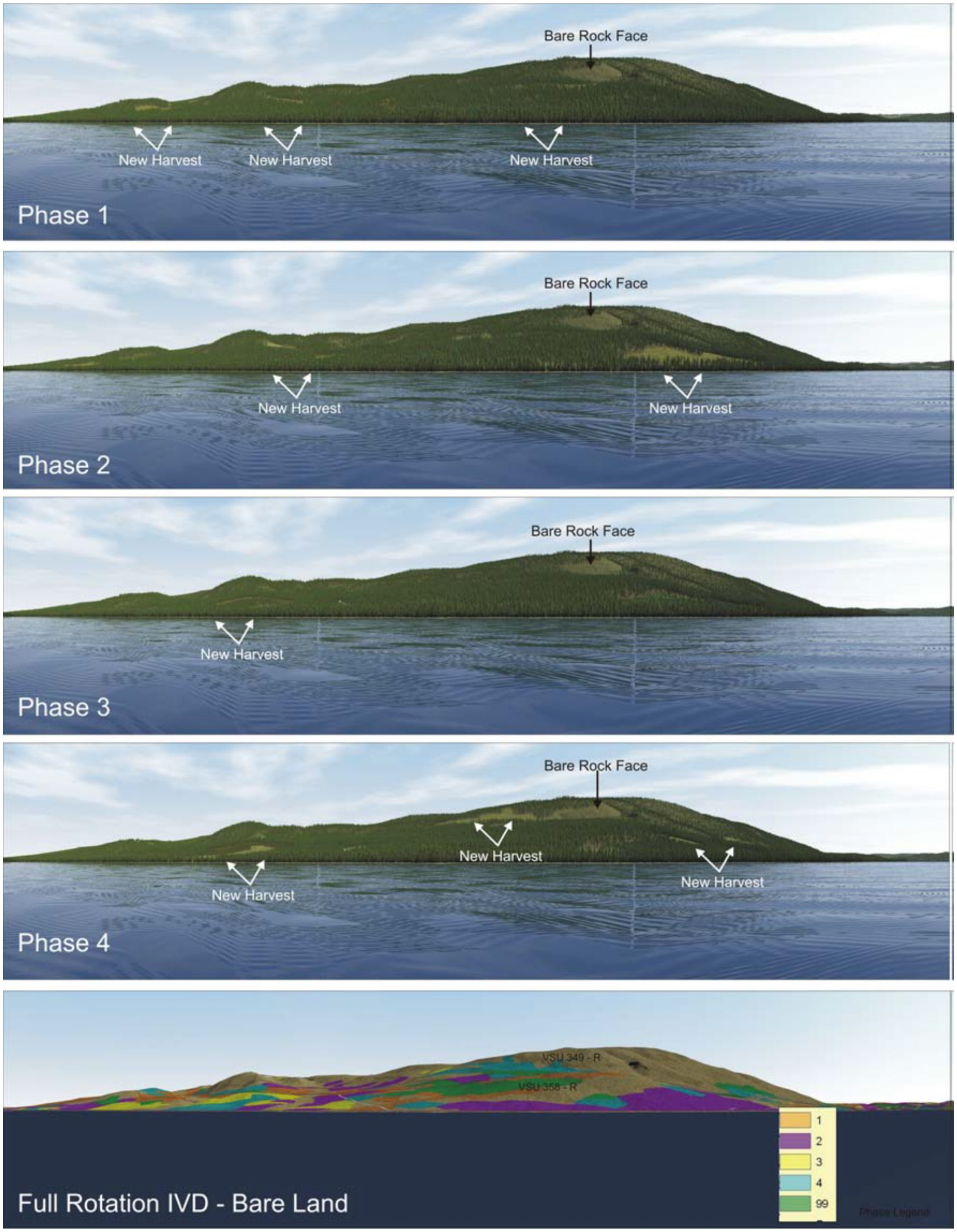


Figure 76 Four-pass schedule projected from the Big Island viewpoint, with all phases shown in bare land image at bottom, with legend. Phase 99 (not scheduled for harvest) is evident in the bottom image in green.

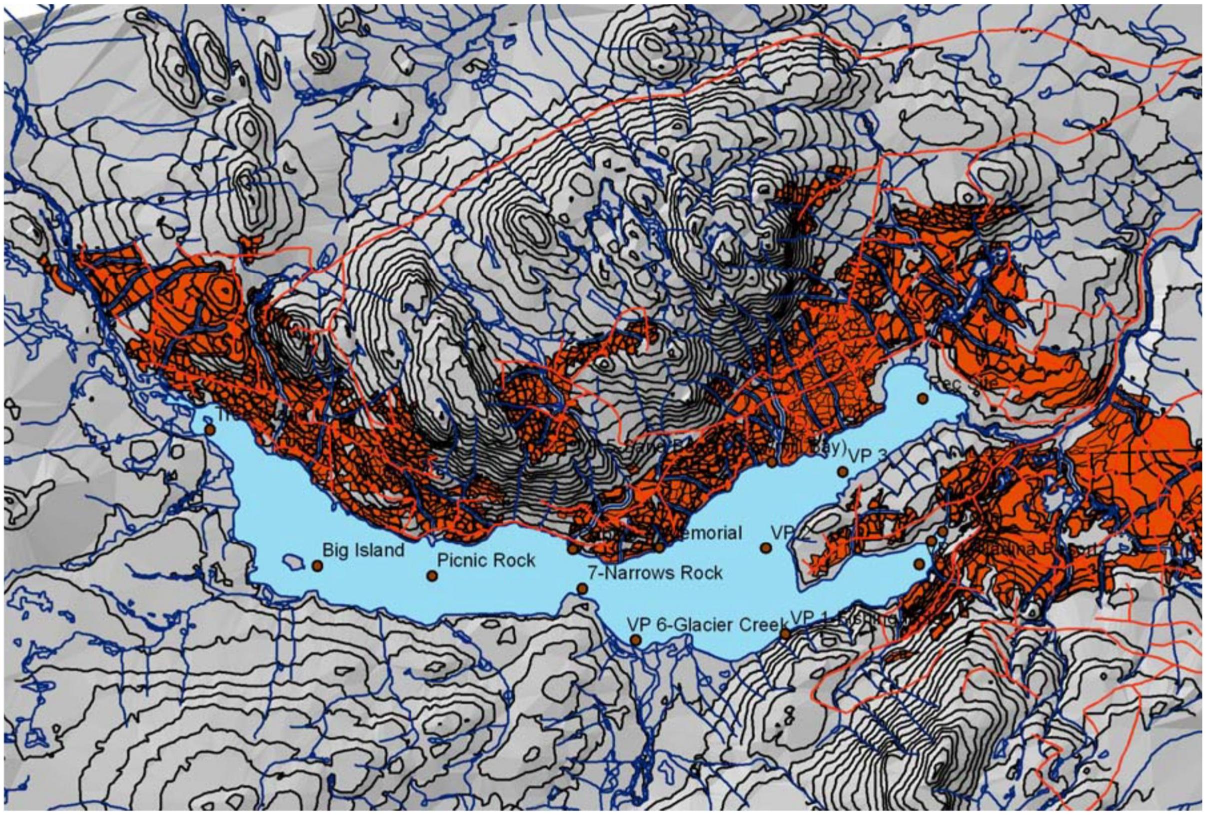


Figure 77 Nadina Lake map with viewpoints (on lake) and harvest units (in red) from the IVDP providing input into the Atlas/FPS automated design procedure over 12 periods, with re-growth added over time.

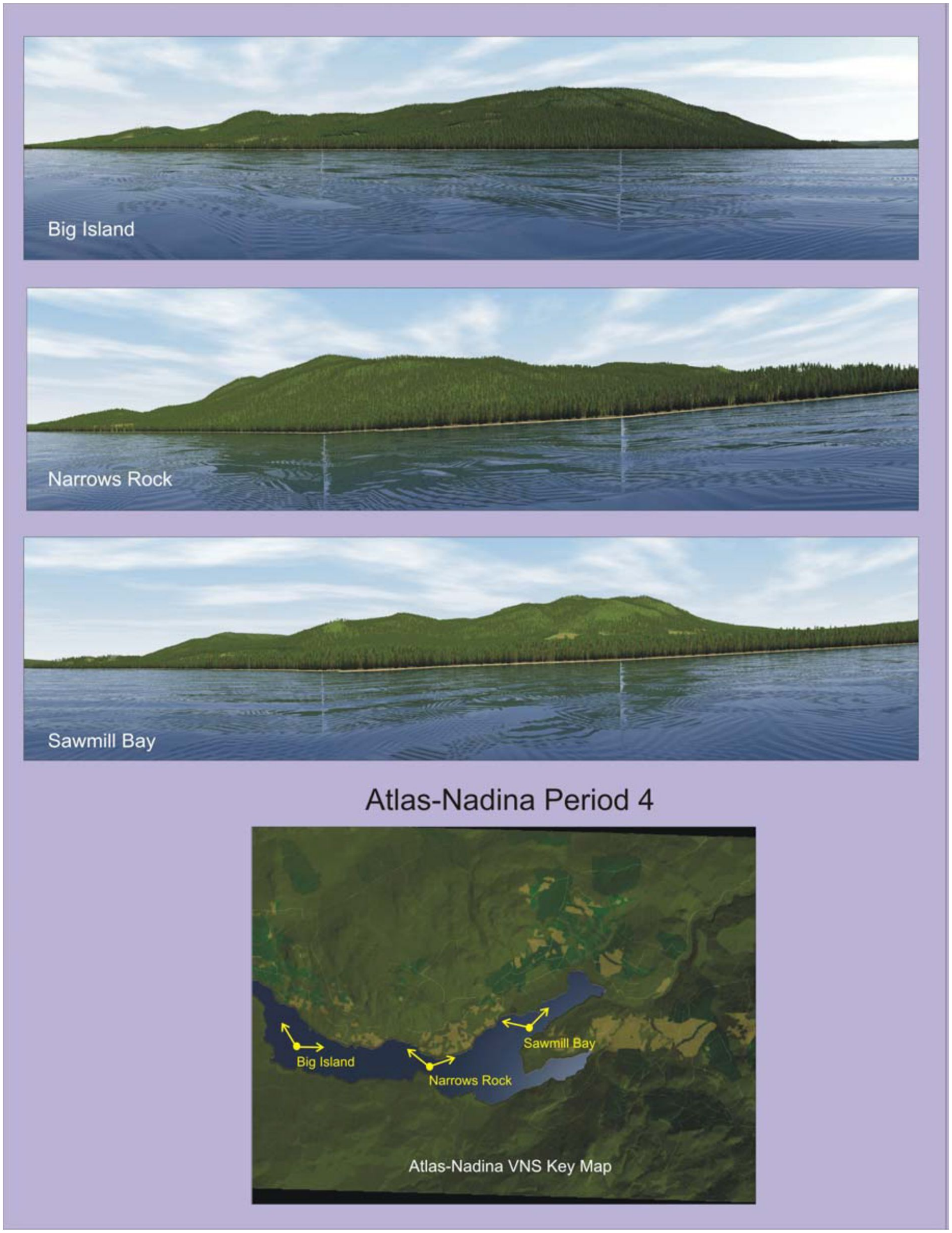


Figure 80 Atlas-Nadina automated harvest schedule - Period 4. New openings in the schedule are pale brown colour, older regeneration is dark green.

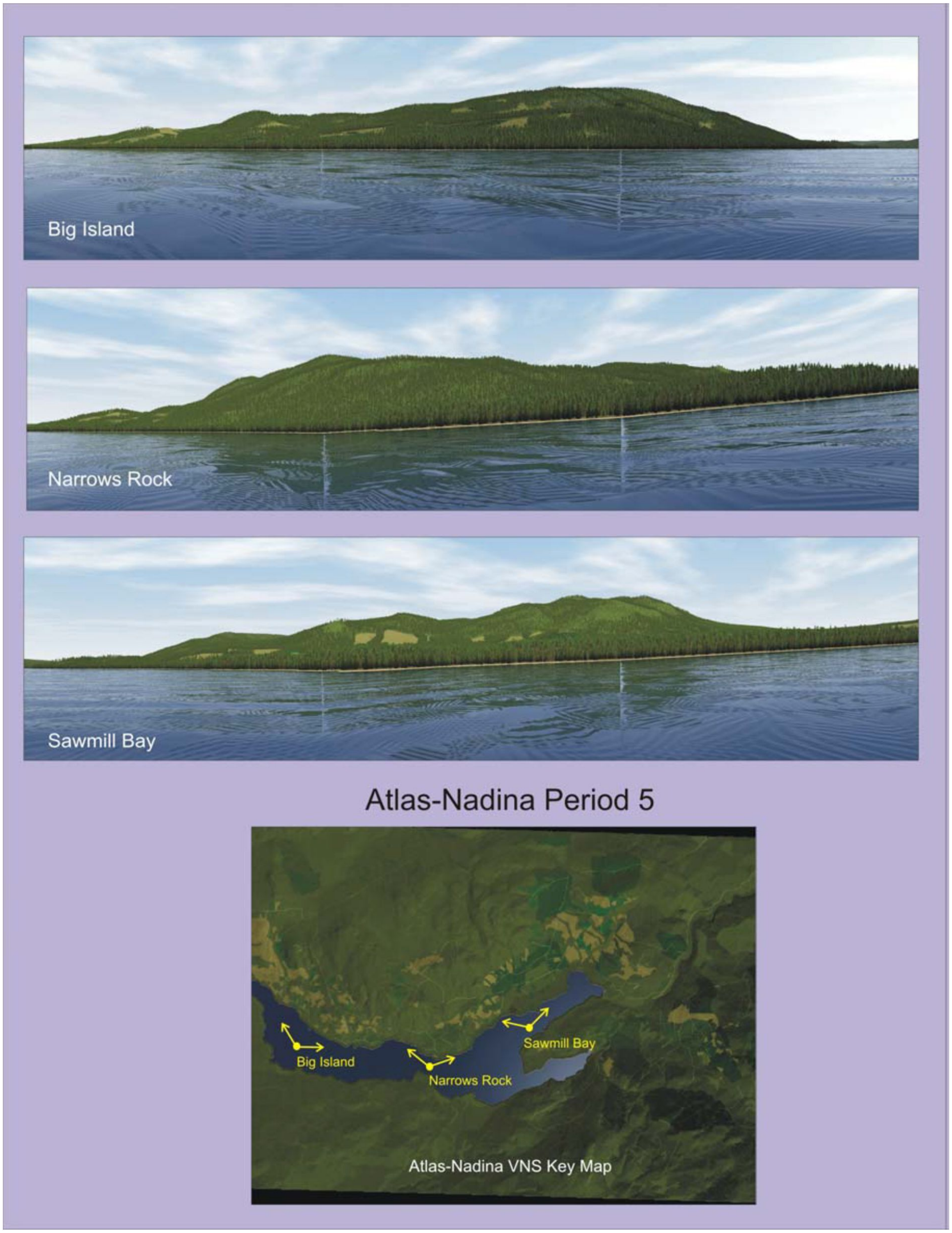


Figure 81 Atlas-Nadina automated harvest schedule - Period 5. New openings in the schedule are pale brown colour, older regeneration is dark green.

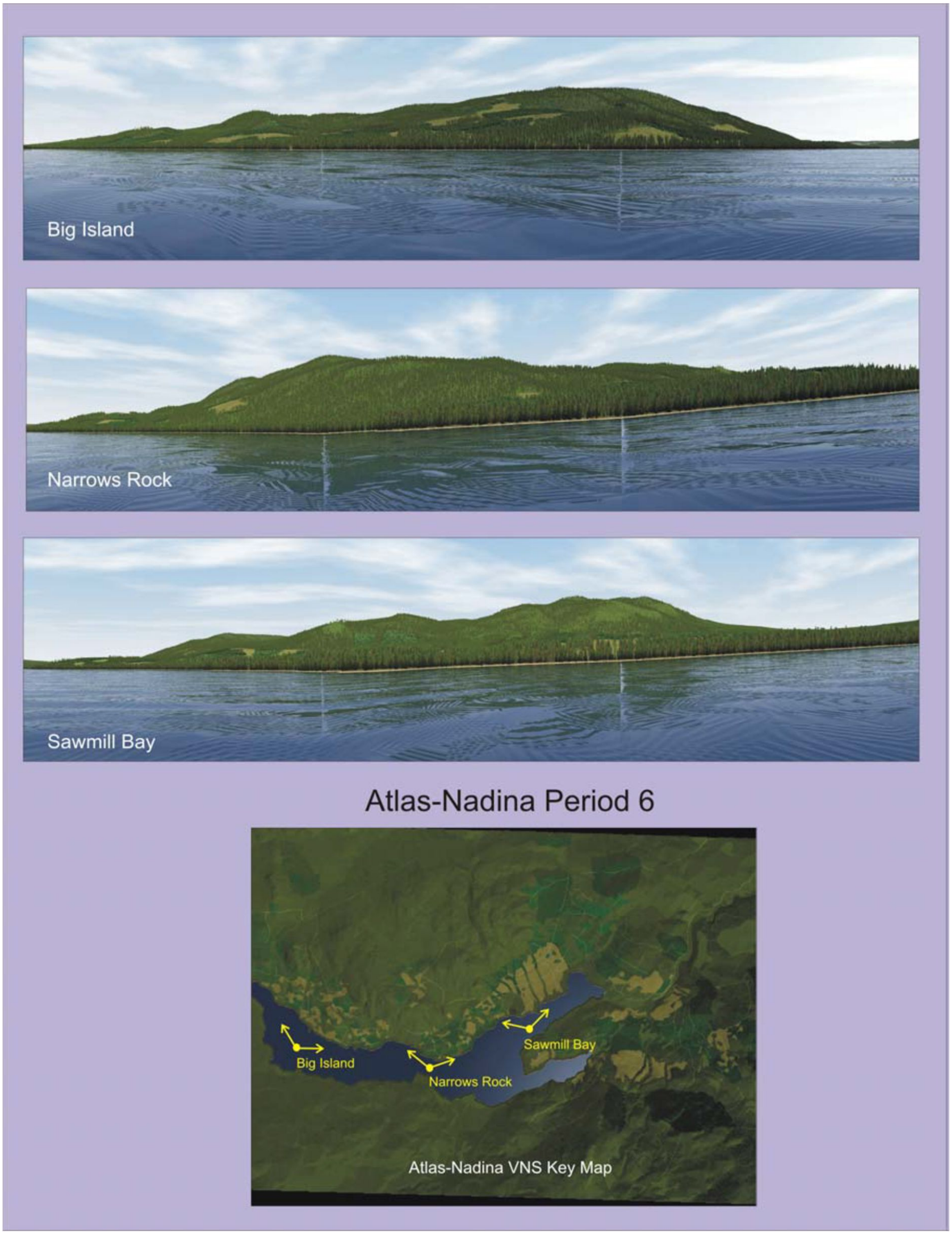


Figure 82 Atlas-Nadina automated harvest schedule - Period 6. New openings in the schedule are pale brown colour, older regeneration is dark green.

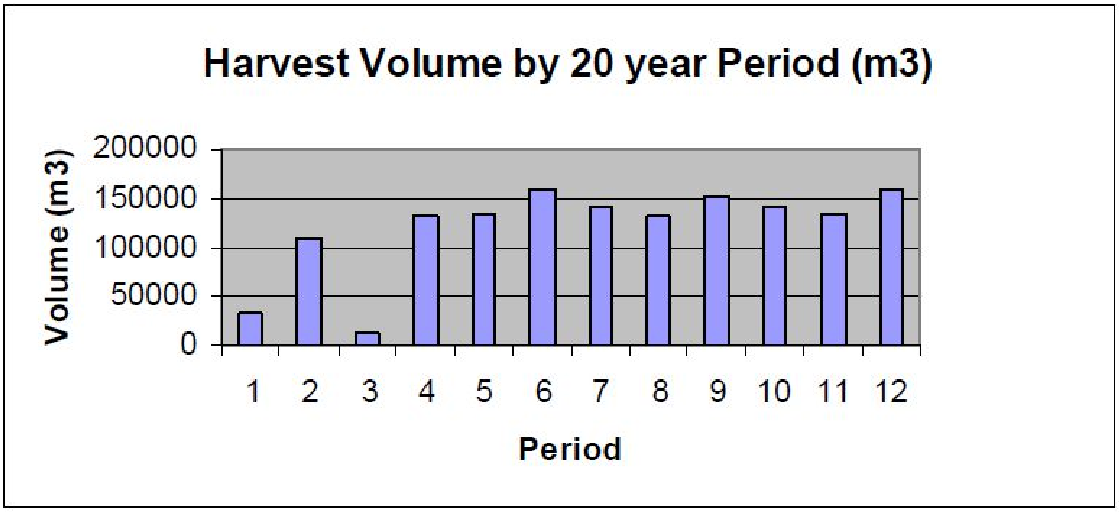


Figure 78 Atlas-Nadina harvest rates by volume in each period.

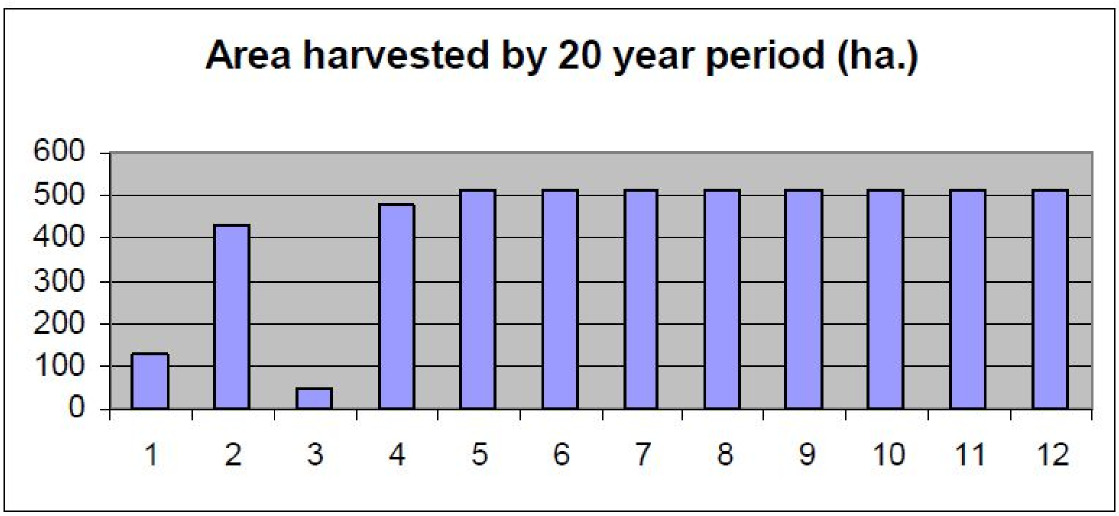


Figure 79 Atlas-Nadina harvest rates by volume in each period.

Findings and Conclusions – a Brief Summary
– see full PDF at UBC Library Vancouver http://hdl.handle.net/2429/28006

6.1.3 Stage 3: Classification; VLI, Plan-to-Perspective
In Stage 3, illumination maps were: classified and compared with Visual Sensitivity Units (VSUs) determined from Visual Landscape Inventory (VLI), slope mapping and times-seen mapping . A discussion of the results of each follows:

1. Apparency Classification; Comparison with VLI

As compared with VLI, apparency mapping was shown to provide a highly detailed map of the locations, patterns, and degree of potential cumulative visual risk within each VSU examined. In contrast, the VSU was assigned just a single overall VAC rating in the VLI without any capacity for differentiation, thereby under-accounting large areas of visual vulnerability and over-accounting for those areas with a lack thereof. The detailed apparency map was shown to quite easily and effectively be used to inform resource management, such as for timber harvesting, or for levels of protection deemed necessary for higher-risk landscapes. The results observed for cumulative apparency with multiple Landscape Control Points (LCPs) (Fig. 42) and additive cumulative apparency (produced by adding individual illumination maps produced for each of the LCPs (Fig. 43) were very similar when colour-coded using the 5-class quantile method. The expected RGB 255 "topping-out" occurred with only 2% of the land-plane area, suggesting that the cumulative approach is not necessarily limiting, and requires further testing with a greater range of landscape types (steepness/relief), and by the number and positioning of light sources. The additive approach would be preferable to the cumulative approach if topping-out becomes significant, perhaps at greater than 5% of the area.

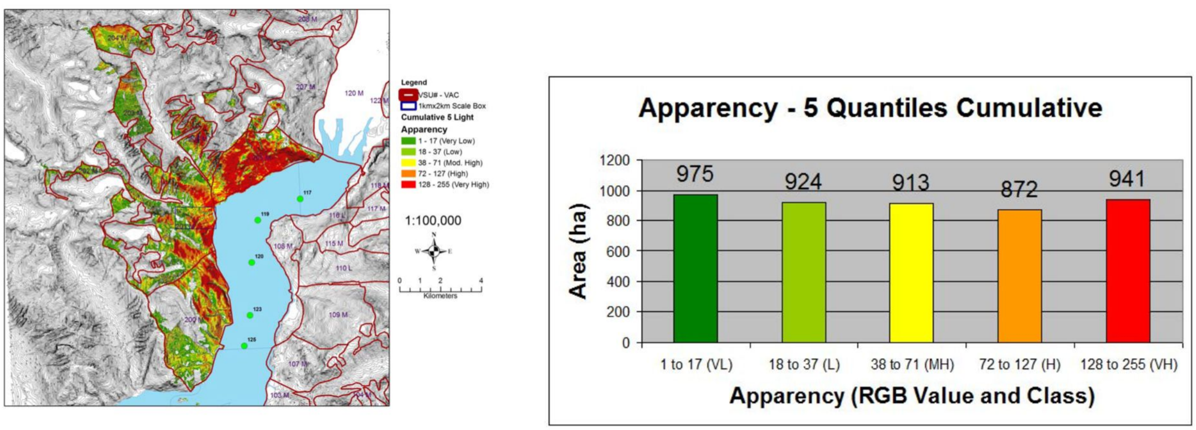
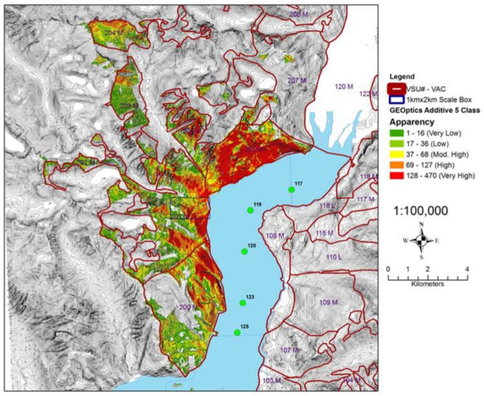


Figure 42 Five-quantile cumulative apparency map and histogram of area in each quantile; VSUs outlined in red.



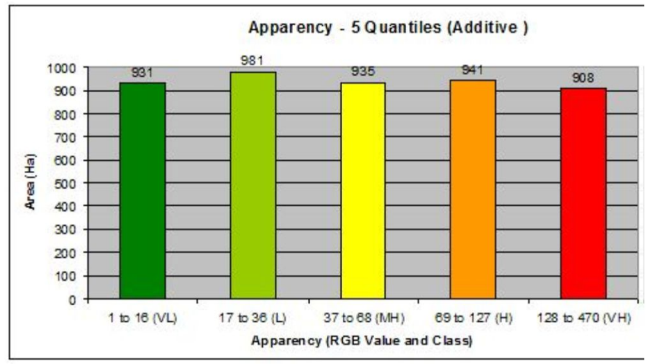


Figure 43 Additive cumulative approach adding 5 separate illumination maps together using raster math, with lights turned on one at a time; using a 5-quantile classification, with VSUs outlined in red.

Comparison of Apparency and Slope Mapping

Topographic slope and apparency, derived from the same terrain models, were compared. Knowledge of the topographic slope is essential, not only for operational planning, but also when refining VQO percentages. In the present VLM system, all steep areas in visually sensitive terrain would equally be assigned more restrictive visual constraints, regardless of viewing angle, including terrain that is oblique to the view. Having considered viewpoint-specific and cumulative viewing angles, apparency was found to be a much more refined, reliable and accurate predictor of visual risk than slope

Comparison of Apparency and Times-seen mapping

A spatial comparison between apparency and ArcGIS times-seen mapping was prepared. Apparency and times-seen are more closely related than apparency and slope. The number of times-seen classes was fixed by the number of viewpoints in the model and therefore was incapable of further refinement without the addition of more viewpoints. A focus group comments reasonably questioned the advantages relative to additional effort, as GIS viewshed analysis is a standard in forest planning. Times-seen analysis is not required in any current procedure, and would itself be an additional GIS procedure (though more simple to construct than apparency). Times-seen mapping does provide for greater differentiation within a VSU, but, unlike apparency, does not consider viewing angles, only if a land-plane is seen or not, regardless of whether the AVI is high or low.

Stage 4: Integration

Conversion of apparency maps from raster (pixels) to vectors (polygons) enabled the linking of the apparency attribute with other databases, such as the VRI forest cover layers and environmental constraint areas. The apparency attribute in the polygons allowed their selection when rendering the visual results of each class in VNS. Polygonization enabled the input of apparency into the UBC Atlas-Forest Planning Studio to produce the Nadina automated planning project, and greatly assisted further analysis and planning, which area described next.

Atlas-Nadina Automated Design Trial

Apparency results derived in the Nadina project were applied to the Atlas-Nadina Automated Visual Design project. The trial was successful in showing the utility of integrating apparency with another planning model (UBC Atlas-FPS). The resulting plan extended over 12 20-year periods totalling 240 years. The harvest patterns appeared to exhibit elements of good landscape design, such as following lines of force, and cohesion. The trial also proved the efficacy and utility of an automated planning system

(Atlas), when calibrated with apparency, to produce acceptable results, from a visual landscape design point of view, over the short and long term. The automated approach could reduce the reliance on forest design professionals, and/or improve the efficiency and effectiveness of harvest planning in the hands of forest operations personnel less trained or less experienced in visual landscape design.

Conclusions - Brief

The concept of landscape apparency represents a new way of looking at the visual landscape, and enables a new tool to spatialize, analyze, and visualize visual risk. Automated apparency mapping reveals hitherto unseen patterns of relative visual risk in the landscape, quantifying and communicating what was previously held only in the "mind's eye" of skilled forest designers. In this study, the scope and framework for the GEOptics landscape apparency model has been defined. The research design enabled the development of procedures and testing mechanisms for its validation. The limitations of the system were tested and made known. The GEOptics apparency model was determined to potentially offer an improved understanding of the landscape for the landscape specialist and field-level resource management professional. It offers a method to refine visual landscape inventory to address known shortcomings of the current system, whenever refinements are to be made.

The system is expected to be useable by land managers without a strong background in visual resource management, though with some guidance and support from widely available VRM specialists and consultants in that field. Apparency can provide a new, reliable, GIS-based inventory measure that would help guide resource planning and design, and enhance current VRM procedures. While clearly not focusing on estimates of scenic quality or scenic beauty, its utilization as a strategic tool could enhance the effective management of the scenic resource. Given its potential for highly detailed stratification of the landscape into greater and lesser visual zones in advance of land-use activity, GEOptics apparency mapping could reduce the reliance on restrictive VQOs being applied singularly across large land units (visual sensitivity units) while protecting or enhancing desired levels of scenic quality. While timber supply factors are broadly derived, the knowledge gained in testing apparency for its relation to plan-to-perspective analysis, when derived for specific landbase areas, can potentially provide an indicator for refining resource supply questions such as in Timber Supply Review in British Columbia, in relation to visual resources. In some areas, this may mean providing greater flexibility for resource supply/management, while maintaining or even enhancing visual quality.

Apparency was shown to be an effective measure for learning more about the landscape – by defining more closely where the challenging (higher risk) areas are located vs. the safer (lower risk) areas for management activity. It is not an issue of "hiding" forestry from view so much as providing surer, better ways to design with nature to "fit" in landscapes which must meet multiple demands. This knowledge can assist development planning and long term integrated visual design and total chance planning. As apparency can be accommodated by automated planning systems such as Atlas/Forest Planning Studio, it can assist scheduling and shows it is capable of helping automate visual landscape design, thereby reducing the current reliance on experts and the currently high level of failure to meet visual quality objectives by current planning methods. GEOptics is expected to be applicable to a wide array of resource planning mechanisms and databases, locally and internationally.

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