Evolution of a Visual Impact Model to Evaluate Nuclear Plant Siting and Design Option[1]

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Abstract: The development of a visual impact methodelegy is reviewed from first concepts (1973) to application.[3/] The method can be used to train evaluators to use explicit criteria (vividness, intactness and unity) to assess change in a setting's visual quality as the result of construction of a nuclear facility, or any other visible alteration. Slides of "before" and "after" eye-level color photographs provide the basis for evaluating these criteria. The model converts these scores into a numerical index of visual impact.

INTRODUCTION

In 1973 the U.S. Atomic Energy Commission funded a study to evaluate environmental, social and economic options for the analysis of nuclear plant siting possibilities (Burnham 1974; Jones, April 1975). Consulting with Battelle Pacific Northwest Laboratories for the AEC, the authors developed a method to measure that elusive variable, "aesthetics." Experimenting with approaches developed earlier by many researchers (Jones, Litton, Leopold, Craik, Zube, et al.) a method was devised by which a small group of individuals using specific criteria can be trained to assess the visual quality of a landscape on an absolute numerical scale of 1-100.

This method has become an established technique for measurement of visual quality. Three main criteria were identified which may be combined into a simple equation to yield an overall, quantified evaluation of landscape visual quality: (1) vividness - a landscape's memorability, (2) intactness - the wholeness or integrity of its order, and (3) unity - the visual harmony of its parts. Use of these criteria diminishes personal bias and helps define the qualitative strengths and weaknesses of a scene. This approach can be applied in a wide range of projects and regional landscape settings, both wild and urban in character.

In 1975 the U.S. Nuclear Regulatory Commission asked the authors to apply the AEC method to determine the visual impacts of various cooling tower options for the Indian Point Nuclear Generating Plant at Peekskill, New York (Jones, November 1975). Ten viewpoints were selected from within the potential viewing area of the plant; each viewpoint was chosen on the basis of viewing distance, observer position and viewing population. Color photographs taken of the existing site from each viewpoint were air-brushed to simulate each proposed cooling tower option, including the vapor plume under "normal" atmospheric conditions.

Slides of fifty such photographs were evaluated at a day-long workshop by a group of architects, landscape architects, environmental planners and urban psychologists, after a two-hour training session in the use of the criteria. The visual quality of the six illustrated cooling tower options was compared to the existing quality for each view, to determine the degree of change from "before" to "after" for each option. This was multiplied by the number of viewer contacts at each viewpoint for an index of relative visual impact.

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[3/] For a detailed presentation of this model, see Burnham (1974) or Jones (April 1975); for its application at Indian Point, see Jones (November 1975).

FORMULATING A CONCEPTUAL MODEL

At first considered to be both intangible and unmeasurable, aesthetics was among eight criteria identified by Battelle Pacific Northwest Laboratories (BNWL) in the analysis of nuclear plant siting options for the AEC. BNWL's multi-disciplinary impact evaluation procedure required a visual impact model which would (a) permit the evaluation of a range of potential facility types, (b) require relatively few evaluators for effective use, and (c) apply to any landscape/facility combination.

The conceptual model required a workable definition of "visual impact." Eventually "visual impact" was defined as "the change in visual quality over time resulting from the introduction of a facility into a landscape setting, as viewed from the surrounding area." To meet the requirements of that definition, we had to develop a reliable procedure to measure "visual quality," one that could be applied to a wide variety of settings. Merely to determine the degree of visual compatibility between the form, line, color, or texture of the facility and its setting was not sufficient for a model required to measure visual impact. An overall scale of visual quality was necessary to serve as a framework, within which actual degree of change could be measured.

An accurate and inexpensive method was required to simulate the appearance of the landscape before and after the introduction of a nuclear facility. To locate critical viewpoints from which a facility would be visible, a method to construct a visibility map ("viewshed") of the proposed facility was needed. Guidelines were then necessary to select representative viewpoints from which to simulate and evaluate alternatives. These individual evaluations at each viewpoint could then be interpolated for the entire viewshed.

The methodology had to be documented as a "how-to" guide in handbook format, with samples of criteria and scoring methods. Both BNWL and the AEC wanted the model to be used to train a team of evaluators to use the method, as well as provide a means to replicate the ratings and recommendations of everyone from the so-called "experts" to the general public. But budget limitations did not permit sophisticated public testing or extensive research.

Comparing the impacts of various facility designs at different sites was another problem, as was deciding on the significance to be given to the number of viewer contacts in relation to the amount of change in visual quality. How could the visual impacts of a nuclear plant with natural-draft cooling towers in a high-quality forested valley setting with a small viewing population be compared to a plant using large cooling ponds in a medium-quality industrialized urban landscape with a large viewing population? Was there any way to measure the extent of change in visual quality in a way that would acknowledge that landscapes of high visual quality are becoming rarer and hence are more valuable than those of low visual quality? Was it possible to compare very different landscapes on one scale of quality?

These considerations led to the following hypotheses, from which the model developed:

(1) A landscape's visual quality can be measured in an unbiased way by trained individuals using explicit criteria.

(2) A change in landscape visual quality can be determined and expressed as a ratio which compares visual quality scores "before" and "after" a proposed alteration.

(3) Viewer population size and sensitivity may modify the severity of visual impact, so long as the relative scarcity or uniqueness of the landscape is also considered within a larger regional context. Such "red flag" indicators protect remote areas as well as unusual natural and cultural sites of less obvious aesthetic significance from being developed solely on the basis of number of viewer contacts.

DISCOVERING A METHOD TO RATE VISUAL QUALITY

Several thoughts were stimulated by the old adage, "Beauty is in the eye of the beholder." Is "beauty" of the landscape determined solely by a person's taste, preference, cultural attitude, perception, feeling or intelligence (as the adage might lead us to believe), or rather does man respond to an intrinsic landscape aesthetic linked more directly to the landscape's expression of process and form?[4/] If there are identifiable landscape characteristics which evoke aesthetic response in man, what are their essential qualities and interrelationships?

The challenge lay in determining and articulating explicit criteria which contribute to landscape visual quality. By using these criteria, we hope to diminish individual bias and provide a more objective basis to determine visual quality than an overall judgement alone. The criteria would also be useful in identifying the qualitative strengths and weaknesses of a scene, and might indirectly suggest design

[4/] For further discussion, see Jones (Spring 1975) and McHarg (1969).

options to improve the quality or to diminish the negative impacts of an alteration.

Our main test for the criteria was whether or not they could be articulated separately, and yet their ratings combined in a simple equation to yield scores which correlated closely with overall mean judgements of visual quality for a given scene. Due to a restricted budget, we had to limit our testing efforts to a small group of critical individuals familiar with a range of landscapes, who could be called upon to provide the equivalent of "expert testimony." Hence we turned to individuals with design-related backgrounds to test the criteria; their experience and insights proved valuable in clarifying the criteria and rating scales developed, and lent credibility to the methodology. (It should be noted, however, that we have successfully trained individuals from a wide range of backgrounds to apply the criteria equally well, and do not consider it an "elitist" approach; a certain degree of familiarity with the definitions and rating scales is all that is required. Later studies have revealed high correlations between "expert" ratings of scenes and those of the general public, although visual sensitivity to specific alterations may vary slightly between interest groups.[5/])

We considered a number of criteria, including complexity, diversity, irregularity, mystery, prominence, variety, freedom from encroachment, distinctiveness, uniqueness, harmony, coherence, and others. These terms were suggested in works by Craik (1972), Crowe (1958), Jones (1966, 1973), Leopold (1969), Litton (1968, 1971), McHarg (1969) and Zube (1973). We found Litton's (1971) definitions of variety, vividness and unity particularly comprehensive. Zube's (1973) report that Kaplan and Wendt found a positive correlation between naturalness and individual landscape preferences also proved relevant.

We eventually tried to use the least possible number of terms, reducing them to those which were the most encompassing and significant, and could be applied easily to any scene. Two criteria which repeatedly proved significant included (a) Litton's "vividness" (using his "variety" as a component contributing to vividness), and (b) the naturalness/freedom-from - encroachment factor (Jones, 1973, Zube, 1973) which we called "intactness." However, numerical comparison between overall visual quality scores with those derived from these two criteria alone were not wholly successful. Another factor was necessary.

[5/] See Blair (1976).

Remembering Frank Lloyd Wright's insistence upon "variety within unity" and returning to Litton's definition we made some evaluations using the three criteria of vividness, intactness and unity. We then found that a simple averaging of these criteria, weighted equally, yielded visual quality scores very consistent with mean overall ratings of various landscape scenes. Testing these criteria with other five-member groups from the design professions produced similar results. Thus we discovered that a landscape's visual quality can be measured by trained individuals using three criteria: (a) vividness - the landscape's memorability, (b) intactness - the wholeness or integrity of its order, and (c) unity - the compositional harmony of its parts. These criteria are briefly illustrated in figure 1.

The method we used both to test and to apply these criteria involves three different approaches or measurement levels, each of which provides independent visual quality scores for a given scene which can then be compared. For level one, an evaluator simply rates overall the visual quality of each scene on a 1-100 scale, where familiar "benchmark" landscapes are used as reference points along the scale. For level two, numerically-scaled definitions for vividness, intactness and unity are applied to yield ratings for the scene as a whole. These criteria are scored on a 1-7 scale for easy comprehension, and then averaged and converted to a 1-100 scale for direct comparison with level one. For level three, the scene is analyzed graphically into its distinctive individual parts[6/] (water, sky, facility, foreground land/vegetation, background hills, etc.) and each part rated (1-7) for its vividness and intactness within the context of the overall scene. In addition, each part is rated according to its degree of visual contribution to the overall scene. This contribution becomes a weighting-factor used to place the scores for each part into proper perspective. Expressed numerically, these equations are:

Level 1: VQ = ________ (scored 1-100)
Level 2: VQ = (V+I+U) ÷ 3 (scored 1-7)
Level 3: VQ = (V'+I'+U) ÷ 3 (scored 1-7)

Where VQ = Visual quality,
V = Vividness of overall scene
I = Intactness of overall scene
U = Unity of overall scene
V' = A weighted vividness score (the summation of vividness of each element times its importance, divided by the sum of all importance scores)

[6/] See Jones (1966, 1973 and Spring 1975).

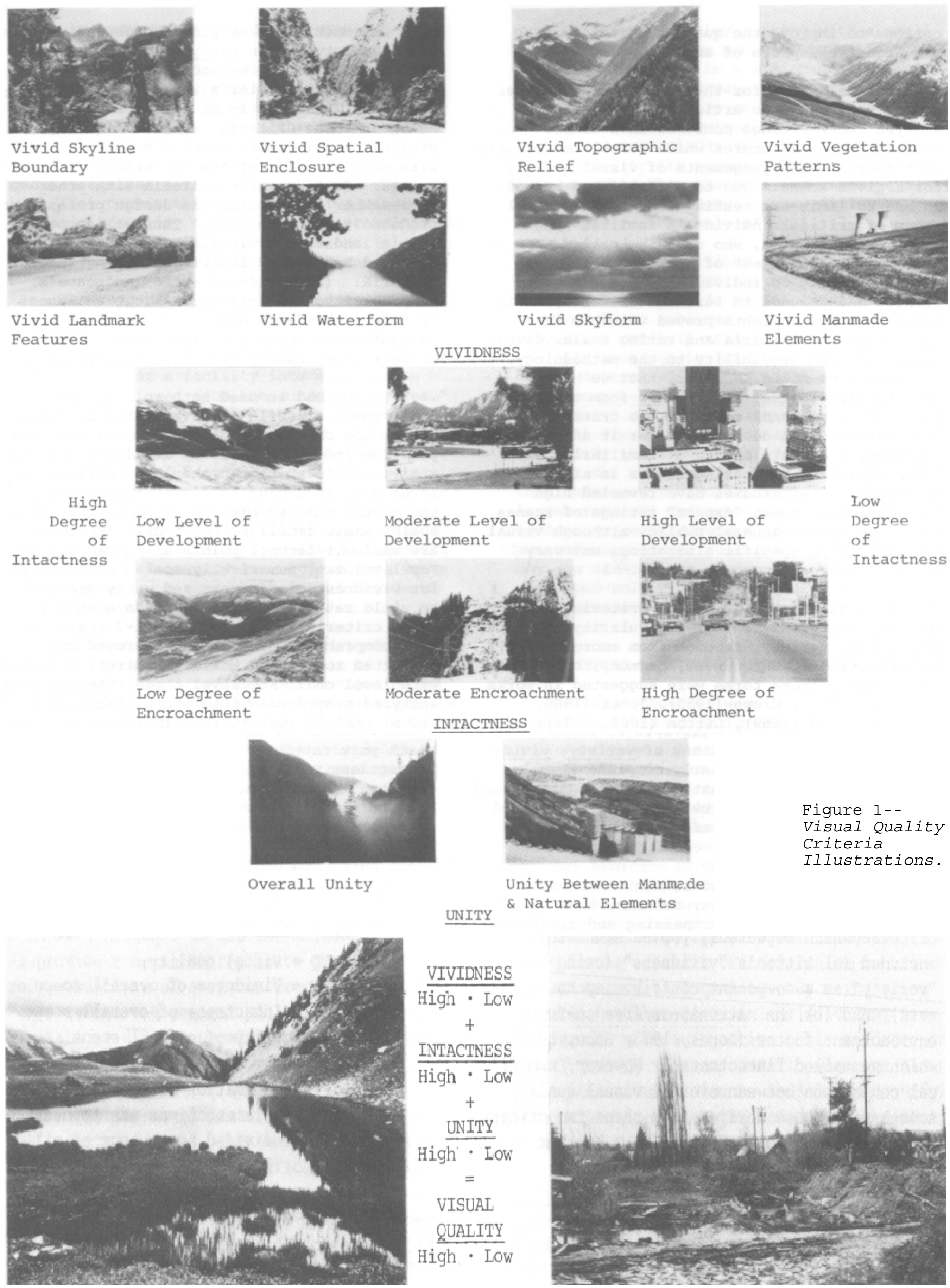


Figure 1--*Visual Quality Criteria Illustrations.*

and I' = A weighted intactness score (calculated as for V').

Measurement level 3 often yields visual quality scores most consistent with level 1, the overall rating. Rather than depend on one level alone, we suggest that all three measurements levels be utilized in the AEC model's visual quality evaluation procedure, and have developed a checklist to score factors for all three levels.[7/]

FILLING OUT THE FUNCTIONAL MODEL

Since the model had to be documented in a handbook format, we developed the step-by-step procedures outlined below.

Step 1--Survey the site for scarce visual resources. In line with Leopold's (1969) idea that unusual landscapes should be protected regardless of their visual quality, this step suggests that the visual resources of a potential site for a nuclear facility be looked at in larger regional landscape context to assess their relative commonness or scarcity. If unusual visual resources are present that would be threatened or altered by the facility, a "red flag" warning (Dee 1973) should be signalled and the site desirability reconsidered in context. This method also helps to protect unique sites in remote areas from being selected for development solely on the basis of low viewer contact.

Step 2--Construct the facility's viewshed. This visibility map documents the surrounding area from which a facility can be seen and aids the selection of representative viewpoints.

Step 3--Estimate population viewer contact with facility. Both resident and transient viewers are considered within the facility's viewshed. The AEC handbook outlines procedures to count number and frequency of viewer contacts per year within a given sector, and theorizes that since residents may become accustomed to the presence of a facility over time, their sensitivity to it may be slightly less than transients.[8/]

Step 4--Select representative viewpoints. Since it would be impossible to simulate and evaluate scenes of all proposed facility alternatives from every point in the viewshed, a method to select a limited number (8-12), of "most representative" viewpoints was necessary. We employed Litton's (1968) criteria of viewing distance (facility in foreground, middleground or background distance zones) and observer position (observer superior, normal or inferior to the facility) to suggest a representative distribution of viewpoints.

Step 5--Photograph the scene and simulate the facility. Views from at least 20 viewpoints are photographed within specified times of day and weather conditions. Then 8-12 views are selected for making facility alternatives and air-brushing. Slides of these simulated photographs are assessed by a team of evaluators.

Step 6--Evaluate visual quality. The team of trained evaluators are shown slides of "before" and "after" photographs and record their scores on a checklist using all three measurement levels of visual quality. Final scores are compared on a 1-100 scale and documented for each individual evaluator. Average scores are determined for the entire group.

Step 7--Determining total visual impact. Final documentation includes the collection of "before" and "after" photographs evaluated with a tabulation of the following: (a) viewpoint name, (b) viewing distance, (c) the "before" and (d) the `after" visual quality score for each alternative as seen from that viewpoint, (e) the ratio of change in visual quality from that viewpoint (numerical difference in "before" and "after" score divided by the "before" score, expressing positive or negative change in the context of original visual quality), (f) population viewer contacts per year, (g) a derived population contact weighting factor, and (h) a visual impact score combining the ratio of change in visual quality (e) and population contact weighting factor (g) . A brief report should accompany this data, summarizing the findings of the visual resource uniqueness survey conducted in step 1.

APPLYING THE MODEL AT INDIAN POINT

In 1975, Jones & Jones applied the AEC visual impact model to determine the impacts of single and double 565-foot high natural draft cooling towers, single and double 370-foot high fan-assisted natural draft cooling towers, and two or four 74-foot high circular mechanical draft towers, alternatives proposed for existing nuclear facilities at Indian Point on the Hudson River near Peekskill, New York (Jones, November 1975). See simulated alternatives from key viewpoints in figure 2, and overall viewshed in figure 3.

[7/] See Burnham (1974) or Jones (April 1975).
[8/] Differential viewer sensitivity issues are developed more fully in Hendrickson (1974), Blair (1976) and Driscoll (1976).

Existing:
Visual
Quality =
34

375'
Tower
Visual
Quality
= 48

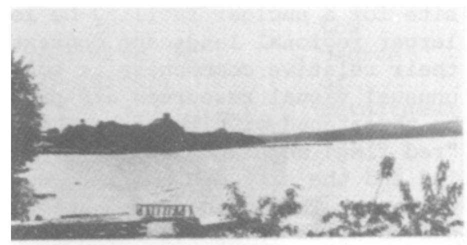
565' Tower
Visual
Quality
= 49

65'
Towers
Visual
Quality
= 56

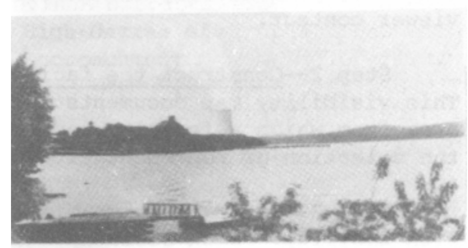
Above: Hudson Overlook Apartments
High Viewing Population, 2½ miles away

Figure 2--*Cooling tower alternatives as seen from selected viewpoints.*
below: Peekskill Waterfront
High Viewing Population, 7/8 miles away

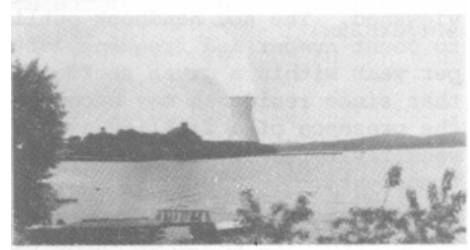
Existing;
Visual
Quality
= 35



375' Tower
Visual
Quality
= 54



565' Tower
Visual
Quality
= 58



65' Towers
Visual
Quality
= 60

Figure 3--*Indian Point shaded viewshed of 565'-high natural draft cooling tower alternative for unit number 2. Solid concentric circles at 1-mile distance intervals.*

All the options evaluated diminish the overall visual quality of the surrounding view-shed, except for the 565-foot and 370-foot tower alternatives as evaluated from two viewpoints for level 2. The taller towers and steam plumes added overall visual interest (vividness) to these two scenes, which offset the reduction of each scene's intactness and unity. Surprisingly, the special-competence group's scores consistently indicated that either of the taller hyperbolic paraboloid tower options diminished visual quality less from most viewpoints than the shorter, less-visible 74-foot high towers.

Simulating the size and density of the vapor plume, as specified by the NRC's consulting meteorologist, was a problem. As often happens in the preparation of an EIS, the meteorological studies required to determine the vapor plume configuration were conducted concurrently with the visual impact study. In fact the billowing plumes we were directed to simulate in all views were the result of an extreme weather condition and would occur less than two percent of the time.

The low circular mechanical draft towers were criticized by the evaluators because the sources of the plume were not visible from most viewpoints, producing the appearance of a major ground fire, geyser or minor volcanic eruption. In contrast, an equally dense plume pouring from the taller towers enhanced their form. The NRC counter-argued our study's findings by pointing out the rare occurrence of such extreme plumes, suggesting a more thorough analysis of the problem would require evaluation of both a wider variety of plumes, and plumeless conditions. The NRC also suggested more exploration of the resident viewers' tendency to accept the presence of vapor plumes over time (USNRC 1976).

EVALUATING THE MODEL'S PERFORMANCE

With the exception of the above-mentioned suggestions to improve the model, its performance has been very satisfactory and stood up well to the tests of time. Using vividness, intactness and unity as criteria for the evaluation procedure have proved to be successful in a wide variety of project applications in wild and urban settings throughout the U.S. In retrospect, the experience gained in the formulation and application of this methodology has confirmed our belief that landscape aesthetics can be measured and dealt with in a tangible way.

Some questions that were unresolved in 1973 have since been answered in subsequent work. In particular, there is an important distinction between visual quality and visual character (Jones & Jones 1978 and Ady 1979). The visual character of a landscape may undergo complete transformation without changes in its visual quality score; the inverse is also true. "Visual impact" needs to be redefined as "the change in visual character and/or visual quality over time resulting from an alteration of the landscape, as viewed from the surrounding area." Visual character is closely related to individual preference; one person may prefer the visual character of a golf course over that of a mixed forest, for example, but the visual quality of both settings could be equal.

Development of criteria to predict visual compatibility between proposed alterations and the landscape setting has continued (Hendrickson 1974, Blair 1976, Driscoll 1976, Jones & Jones 1978). These criteria can be applied to large landscapes to assess the potential visual impacts of linear features such as transmission lines, highways and roads, making route selection and alignment decisions easier. The criteria can also be used to suggest design changes to increase visual compatibility and diminish change in (or even enhance) visual character and quality. Techniques to classify the landscape undergo refinement continually (Jones 1966, 1973; Jones & Jones 1974, 1978; Blair 1976; Driscoll 1976; Ady 1979). Viewer sensitivity issues have been identified and dealt with in a more sophisticated manner (Hendrickson 1974; Blair 1976; Jones & Jones 1978; Ady 1979). An empirical model has also emerged for determining the visibility levels of landscape elements at various distances in relation to an object's size and degree of contrast with its setting (Driscoll 1976).

In order to evaluate visual quality in urban settings the definition of intactness has been expanded to mean "the integrity of visual order in the natural and man-built landscape, and the extent to which that landscape is free from visual encroachment" (Jones & Jones 1978). We hope to continue to expand ways to manage the visual resources of our national landscape.

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