# A POSSIBLE SET OF ECOLOGICAL GUIDELINES FOR ENGINEERS

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"design with nature"
(McHaig 1969)

SUMMARY: An outline of a possible set of ecological guidelines for engineers is given. It is based on the complementary approaches of ecological principles, environmental factors, natural landscape units (their properties and limitations) and uses (their requirements and effects). The emphasis would be on biological factors and interactions.

## INTRODUCTION

The theme of the 1971 Conference Symposium (New Zealand Ecological Society) was the relationship between ecologists and engineers. This had been prompted by an inquiry from the New Zealand Institution of Engineers late in 1970 of the feasibility of ecologists drawing up biological and ecological guidelines for the use of engineers in planning their works. The following are suggestions on the form which such guidelines could take. The help of other members of the Council of the Ecological Society is gratefully acknowledged.

It was clear at the outset that recommendations suitable for all likely conditions would be impossible. Rather, the objectives would be to give the engineers sufficient background of ecology and ecological viewpoint for them to be aware of some of the biological implications of their activities so that they would know which biologists to consult and the type of information they require.

These requirements may imply some form of a handbook or bulletin of sufficient length to give the required perspectives, and yet brief and detailed enough to serve as a reference. Such guidelines would necessarily have to be attuned to the New Zealand situation.

The engineer-ecologist relationships could be approached four ways

(a) Explanation of general ecological principles.

(b) Identification of the environmental factors relevant to biological, engineering, social and economic considerations.

(c) Examination of the properties of particular landscape units or ecosystems, and the activities or uses each is suited or unsuited for.

(d) Consideration of the uses or activities contemplated, e.g. what demands and effects these have on the environment in relation to the demands of other existing or potential uses.

The four approaches are complementary but overlap since they are based on the same ecological concepts. The advantage of the multiple approach is that it allows several points of contact when used as an initial reference—as well as allowing more condensed presentation under each section.

The following is the type of information that might be included under each of these approaches.

## ECOLOGICAL PRINCIPLES

Consideration of ecological principles would be brief, their only purpose being to serve as an introduction or background for the other approaches.

*Examples of Ecological Principles*

Hydrologic cycle
Mineral cycles

carbon, oxygen, nitrogen, macro- and micro-nutrients
Energy—producers, consumers, decomposers, food chains, food webs
Life cycles
Niche and ecological amplitudes
Environmental relationships

Engineers are probably conversant with the hydrologic cycle and it could be used to demonstrate that phenomena which are simple in concept are often complex in detail. For example, in a particular engineering situation there may be important differences in runoff and infiltration rates of vegetations and soils of similar types.

Outlines of mineral cycles could indicate that they are equally complex in detail but more closely dependent on plant and animal processes.

The next basic concept of biological energetics —with its broad functional subdivisions into producers, consumers, and decomposers—would demonstrate the interdependence between species in food chains or food webs in particular situations.

Engineers should be shown the intricacies of the life cycles of living things, which in general have a number of stages or transformations, each having particular requirements and limitations, and which are different in detail for each species. It should be stressed that, unlike inanimate objects, the continued existence of a species depends on a continuum of all the stages of its life cycle. Life cycles of animals could be demonstrated using species whose various stages are separated geographically as well as environmentally (e.g. whitebait and eels) to indicate that engineering projects may have effects at points distant in space or time.

The concepts of niche, ecological amplitude and environmental relationships are all concerned with the interactions between living things and the environment. If biologists claim that ecology is relevant to engineers, then they have to demonstrate the importance of environmental interactions, particularly those concerning physical aspects of the environment.

A functional rather than a descriptive approach to ecology is suggested.

## ENVIRONMENTAL FACTORS

Factors to be taken into account by different groups in the total planning of a particular engineering project could be grouped under physical, social or economic, and biological.

The physical environmental factors to be noted should include more than those known to be of direct importance to engineers. The social or economic factors would be those concerned primarily with human welfare.

*Examples of Physical Factors*

Suitability for foundations
  (rock strength, compressibility, earthquake stability)
Water supply
  (rainfall, water table, ODB, sediment load, topography, drainage, etc.)
Sewage disposal
  (amounts, fluctuations, rainfall, soil drainage characteristics, air temperatures, etc.)
Climate
Etc.

*Examples of Social Factors*

Population density
  (mean density, distribution, residential versus industry, ethnic origin, income).
Land values
  (population density, occupations, climate, etc.)
Mental health
  (population density, crime incidence, mental health, recreation)
Scenic values
  (locality, population origin and upbringing, topography, climate, etc.)
Historic place values
  (age distribution of population, history of population, ethnic composition).
Etc.

The biological environmental factors would be those principally concerned with the inter-relationships of plants and animals and their interactions with man and the physical environment.

*Examples of Biological Factors*

Species present
  flora composition
  fauna composition
  numbers
  distributions
  functions or niche
  environmental preferences and tolerances
  life histories
  Etc.

Species relationships
- food chain relationships
- interdependence
- any unique ecological communities

Biological factors important to society and economics
- agricultural lands—types, potentials and distribution
- exploited species—densities, distribution, behaviour, tolerances, etc.
- breeding grounds, etc., of species economically important elsewhere
- sport or recreational species
- scenic reserves
- Etc.

Biological factors important to engineering
- daily and seasonal bird flyways in relation to airports
- deer and opossum damage in catchment runoffs
- evapotranspiration rates of different types of vegetation

Such a subdivision of environmental factors into physical, biological and social or economic is somewhat artificial. Engineers will know the physical factors that are of direct relevance to a particular project. Similarly, townplanners, economists, landscape architects, social workers, etc. have their interest and training in the social and economic factors of human welfare. The particular competence which biologists and ecologists have is in plants and animals and their interrelationships. It is the probable effect of these biological interactions on the objectives of an engineering project, or which would be affected by engineering projects, which would be stressed.

The primary purpose of listing environmental factors would be to make the various groups involved in a project aware of the types of environmental considerations which allied groups have to assess, whether they be ecologists or town planners.

A second and ecologically more significant purpose would be that as each factor is studied it will become apparent that while its distribution may differ from that of other factors there will, on occasions, be a strong coincidence in distribution of several factors. These considerations would break up the landscape into units with different properties. Ecologists might call them ecosystems. The engineer would thus be made aware that his engineering project, involving changes in one or more factors, must be superimposed on a zoning already present—the units of which will probably react differently to any change.

Where the environmental factors can be listed, and where some values judgment can be made, it may be possible to delineate some of the areas of conflict or compatability between engineering and environment (e.g. see McHaig's 1969 method).

## NATURAL LANDSCAPE UNITS AND THEIR CHARACTERISTICS

The third way in which engineer-ecologist relationships could be approached is through natrual landscape units or ecosystems.

*Examples of Landscape Units*
- Marine
- Continental shelf
- Rocky foreshore
- Sandy foreshore and dunes
- Coastal wetlands
- Estuary and tidal lands
- Riverbeds
- Floodplains
- Beech forest
- Pinus radiata forest
- Tussock grasslands
- Alpine rocks and screes

The ecosystem approach would have advantages in that by its nature it represents integrations of particular physical and biological processes. The New Zealand landscape would have to be subdivided into units or ecosystems having a bias towards human use and engineering considerations, yet with particular emphasis on the biological interactions. The recognition of suitable natural units is likely to be most difficult in urban areas and rural farming areas. These are the areas most often involved in engineering projects.

The objective in discussing each type of ecosystem would be to reveal the basic dynamic processes and biological interactions and from this the potential uses to which it is suited or unsuited. For example, flood plains are generally suited for intensive agriculture because their soils rejuvenate naturally, water supply is good, and they are not suited for building projects because of flood risk. Another example is the sand-dune ecosystem.

## SAND DUNES

*Littoral*

Ecology: Wave action and currents give continuous resorting and movement of sand. Few animals are adapted to this environment.

Engineering implications: Not suited to large structures because of poor stability; permanent structure would impede movement of sand along shore; withstands intensive recreational activities e.g. swimming, surfing.

*Beach*

Ecology: Sand thrown up by wave action, dries and is blown inland. Plant and animal materials thrown up by waves (seaweed, shells, wood), supports specialised groups of scavangers, carrion feeders and decomposers. Some specialised animals occupying intertidal region where their zonation is related to tidal levels and substrate stability.

Engineering implications: Not suited to buildings because of instability and susceptibility to storm damage; buildings would impede the landward movement of wind blown sand and interrupt the development of the normal dune complex; beach areas can generally withstand intensive recreational activities; biological decomposers minimise the effect of man-induced pollution.

*Fore-dune*

Ecology: Lessened deposits of salt-spray and lower salt content in ground water allows specialised plants to establish and develop. Increased surface roughness caused by these results in sand deposition and dune buildings. This foredune is the main determinant of sand stabilisation and development further inland.

Engineering implications: Foredune and its vegetation critically important; broaching, as for ground level buildings, should be prohibited as this leads to blowouts; vegetation must be protected at all times.

*Trough*

Ecology: Subject to fluctuating water table and scouring by wind. This leads to ablation of the sand in the trough area until the water table is reached and swamp type vegetation develops.

Engineering implications: More sheltered and biologically more resilient than foredune area; only limited suitability for modification and building.

*Hind-dune*

Ecology: Less salt spray and more available ground water allows growth of a greater range of plant species. The plants promote the deposition of a second dune which gives protection to all areas behind it.

Engineering implications: Similar to those for the foredune but somewhat more tolerant.

*Back-dune*

Ecology: As the area immediately landward of the hind dune it provides maximum shelter and greatest plant diversity and, in regions of forest, the first development of a tree cover.

Engineering implications: Biologically this is the most stable area and in terms of shelter and elevation is the preferred site for the engineering activities such as building construction. Any fill material should come from the beach and not from the dune areas.

## USES: THEIR REQUIREMENTS AND EFFECTS

A fourth general approach could be a list of the uses to which the landscape can be put with some statement about what each of these uses requires from the environment, and in turn what effects it has on the environment. A few are listed.

*Examples of Uses, Activities or Operations* (from Nicholson 1970)

Forestry
- Planting of timber
- Felling of planted timber
- Felling of natural or semi-natural stands
- Establishment and maintenance of amenity woodlands, shelter belts and windbreaks, etc.

Fisheries
- Offshore fishing
- Inshore fishing including shell fishing
- Fish hatcheries
- Trout and eel farming
- Etc.

Extraction of minerals
- Sand and gravel
- Brick clay
- Road metal
- Limestone
- Coal
  - — opencast
  - — underground
- Etc.

Electricity supply
- Hydro-generation
  - — upland rivers and catchments
  - — lakes
- Coal generation
- Nuclear generation
- Transmission and distribution
- Etc.

Transport
- Roads
  - — widening, straightening, maintenance
  - — new roads and motorways
- Railways
- Ports and harbours
- Airfields
- Etc.

Recreation
- Aquatic
  - — swimming and bathing
  - — sailing
  - — motor boat
- Etc.
- Land
  - — playing field types
  - — golf
  - — shooting
  - — model aeroplane
- Etc.

Agriculture
- Cropping
  - — cereal
  - — vegetable
- Etc.

Horticulture
  - — fruit trees
  - — berry fruits
  - — floriculture

Pastoral
- Sheep
  - — wool
  - — meat
- Cattle
- Pig
- Etc.

The listing of an activity may, in some instances, be sufficient to indicate the probable environmental requirements and effects. In others they may be relatively simple to state (e.g. sand and gravel extraction).

*Examples of Requirements and effects of Particular Activities*

Sand and gravel extraction

Area affected: Many coastal and river valley sites and areas of glacial or lacustrine deposits, particularly near population centres.

Requirements: Deep deposits preferably unincumbered by tall rooted vegetation or high water table, but water must be available.

Effect: Often causes pollution of rivers by gravel washings. Often beneficial to wildlife in providing water habitats. Supply geological information.

While the requirements and effects could be considered in terms of physical, biological and social and economic factors, particular attention would be directed to the biological interactions. At some stage in planning it is necessary to be able to state all the relevant environmental factors for each conflicting use in an area. It would only be by identifying and considering all factors that their interactions and implications could be assessed. Whether these could be usefully summarised in all instances is doubtful.

## GENERAL

As stated in the introduction, any guidelines must aim at acquainting engineers with the biologically important aspects of their planning and construction. These guidelines should be in the form of material to which engineers can refer. Four complementary approaches are suggested.

The handbook envisaged would have large sections of tabular material in the form of check lists and reference lists, interspersed with explanatory text. Where possible direct quotation of published material would be used. There is likely to be a small margin between giving sufficient information to be useful in particular instances and the handbook being general enough and short enough to be used as a general reference. This would require a compromise between the need to refer to more detailed texts and the value of having the information within one cover.

The object of such check lists is to define the problem and areas of conflict of particular engineering projects. Some discussion could be made of the techniques being developed to establish the compromise position between such points of conflict.

Such guidelines would be the first point of contact between engineers and ecologists. Lists of appropriate New Zealand authorities for specialised information could be placed under each heading in the sections on 'Uses and Their Requirements', and 'Natural Landscape Units'.

*Examples of Sources of Further Biological Information*

Rocky foreshores: Marine Department, Wellington; Botany and Zoology Department, University of Auckland; Portobello Marine Research Station, University of Otago; Zoology Department, University of Canterbury.

Coastal Wetlands: Wildlife Service, Department of Internal Affairs, Wellington; Acclimatisation Societies; Botany and Zoology Departments, Universities.

Irrigation: Winchmore Irrigation Research Station, Department of Agriculture, Ashburton; Agriculture Engineering Institute, Lincoln College.

Again the difficulty with such a listing is to make it detailed yet short enough to be useful. This would require some assessment of the expertise of various groups under different headings.

However, the guidelines should attempt to give more than an indication of the facts and factors as ecologists see them. They should also attempt to impart some ecological perspective by way of annotated bibliography. Some examples might be:—

What is ecology and what are its aims?
- a religion (White 1967)
- a thing, a bounded area, or a point of view (Scott 1967)
- to guard the interest of natural resources?

Natural resources and their exploitation
- stock, flow, or biological resource
- competitive, complimentary or supplementary products (Frengly 1969)
- the earth—a horn of plenty or a space capsule?

Conservation
- preservation, protection, refuge or resource management? (Nicholson 1970)

Elements of rational planning
- 'we can never do merely one thing' (Hardin 1969)
- 'capabilities of ecosystem, level of technology, economic demands, social pressures' (Lewis in Van Dyne (1969)

Utilising an ecosystem
- productivity or stability? (McNaughton 1967)
- seral or climax? (Odum 1969)

What are the costs and who pays?
- modern farming requires expenditure of 4-5 calories of energy, mainly fossil fuel, for every calorie produced. (Wiegert and Evans 1968 quoting Borgstron)
- raw materials, labour, education, accidents and diseases, cleaning up and prevention of pollution—internal or external costs? (Hardin 1969)

Planning with incomplete information
- maximum gains or minimum losses?

Outlook
- "not peace, ecology!" (Hardin 1969)

Finally, if ecologists accept the challenge to prepare such a set of guidelines for engineers they will discover that it requires much reassessing of the utility of ecology, for to quote Cragg (1969).

"It is one thing to talk about the ecological point of view; it is another to demonstrate it in action."

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