centro de educación continua

division   de   estudios   superiores

facultad   de   ingeniería,   unam

EVALUACION DE PROYECTOS DE INGENIERIA AMBIENTAL
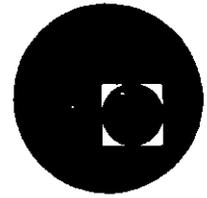
ENVIRONMENTAL ASSESSMENT, AND
INDUSTRIAL IMPACT STATEMENTS

by

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University of Oklahoma

1.0 Areas of Conflict

Production and Conversion of resources to useful
products, creates residuals, use nature, consumes
natural resources

-verses-

Disruption of the intricate web of relationships between
living organisms

-such as-

Aswan - Power-reduces fish in Mediterranean - reduce fertility
of Nile - Increase snails

St. Laurence - Transport sea lamprey predatory on trout, kill
lamprey add Salmon, Salmon contains DDT.

Santa Barbara Channel - Oil blow out erupted.

-so-

Growth, energy 18%/year, population, 1½%/year, residuals
27%/year, agriculture - 3-4 fold, economics - scale,
energetics, 8%, etc.

International ⟨→Inc →Life style   wisdom, small is beautiful, fair
is foul, foul is fair.

2.0 Industry and Government

Misplaced economic incentives - price fails to account for
environment damage.

Social Damages

Failing to or underpricing spawns pollution

Property tax leads to rapid amortization - through quality
degradation.

Poor land use, favor industry, high density housing costs,
more in public service, produce less taxes.

High premium on consumer goods

Federal subsidies, catchup,
Private enterprise verses
Collective Return

Neighborhood Effect

Public works, defense, roads, etc., but uncoordinated
decisions of individual destruction.

Private Luxury

Public Poverty

Concept of common property resources, inherently, social
rather than economic.
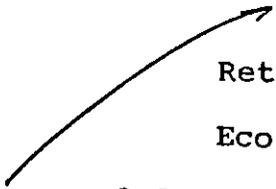
Common law, Res. communes.

Common property (Environment) subject to congestion, filling
up, damaged use to next consumer.

Idea of carrying corporate search for abstracts.

Residual of conversions - impacts on
Renewal resources - are there really any other?

Profit/Loss
Benefit/Cost ⎤ mickey mouse

Return of residuals to common property environment

Ecological Low

3.0 Government Objectives

Green Book, Blue Book *Print #79.*
Economic Efficiency
Regional Efficiency
Quality of Life
Quality of the Environment

Now Economic & Environment

Not parallel - By Economic importance against environment.

Conceptually .

Resources Management   Modified EcoSystems

R   Hunting, Fishing   Wild
E   Waters
V   Should be
O   │   Partnership │ Losses
L   │   │   │
U   ▼   Gains   ▼
T   Manufacturing, etc.   Feast or Famine
I   │   │
O   │   ▼
N   ▼   Finite Resource
S   Information   │
                                                    ▼
         Health   Orchard Garden
         Education
         Security   more people   New Ecobalances
         Employment   Higher lifestyle
         Growth   ▼ Population control

4.0 Technology/Management, etc.

Deficit -- Impact studies -- short term

Assessments

Future -- Joint planning --

Environmental law - Solomonic
Environmental Economics - B/C C/E
Technology - Recycle, Economies, use reduction

Environmental System - Air, water, soil, stds., cost., etc.

System approach - Sim, Gaming, Optimization *(model)*
                                             (POP)

5.0 Assessment Practicum

Nat. Env. Policy Act

Legal Bases, Regd., etc.

6.0 Legal Basis

National Environmental Policy Act (NEPA)
Clear Air Act (CAA)
Federal Water Pollution Act (FWPCA)

EPA Statutes
Section 309 - 110 Clean Air
CAA   Section 112 - 307 Impacts

FWPCA Hazardous.
Section 301, 302, 304, 306

3

GUIDELINES FOR ENVIRONMENTAL INVENTORY, AND ASSESSMENT
INFORMATION NEED ACCOUNTS

A. The environmental impact of the proposed action;

B. any adverse environmental effects which cannot be avoided should the proposal be implemented.

C. alternatives to the proposed action;

D. The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

E. any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

SUBMODELS (impacts)

Land use compatibility
Water use compatibility
Heat dissipation
Chemical discharges
Sanitary wastes
Biological impact
Monitary requirements
Radioactive discharge
Construction effects

GOALS INTERPRETATION

Unavoidable Effect and Alternates

Irreversible and irretrievable commitments.

Short-term vs. long-term productivity

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TABLE 1

POTENTIAL ENVIRONMENTAL IMPACTS OF A TRANSPORTATION FACILITY
(by Phase of Project Development)

Planning and Design Phase

1. Impact on land use through speculation in anticipation of development.
2. Impact of uncertainty on economic and social attributes of nearby areas.
3. Impact on other planning and provision of public services.
4. Acquisition and condemnation of property for project, with subsequent dislocation of families and businesses.
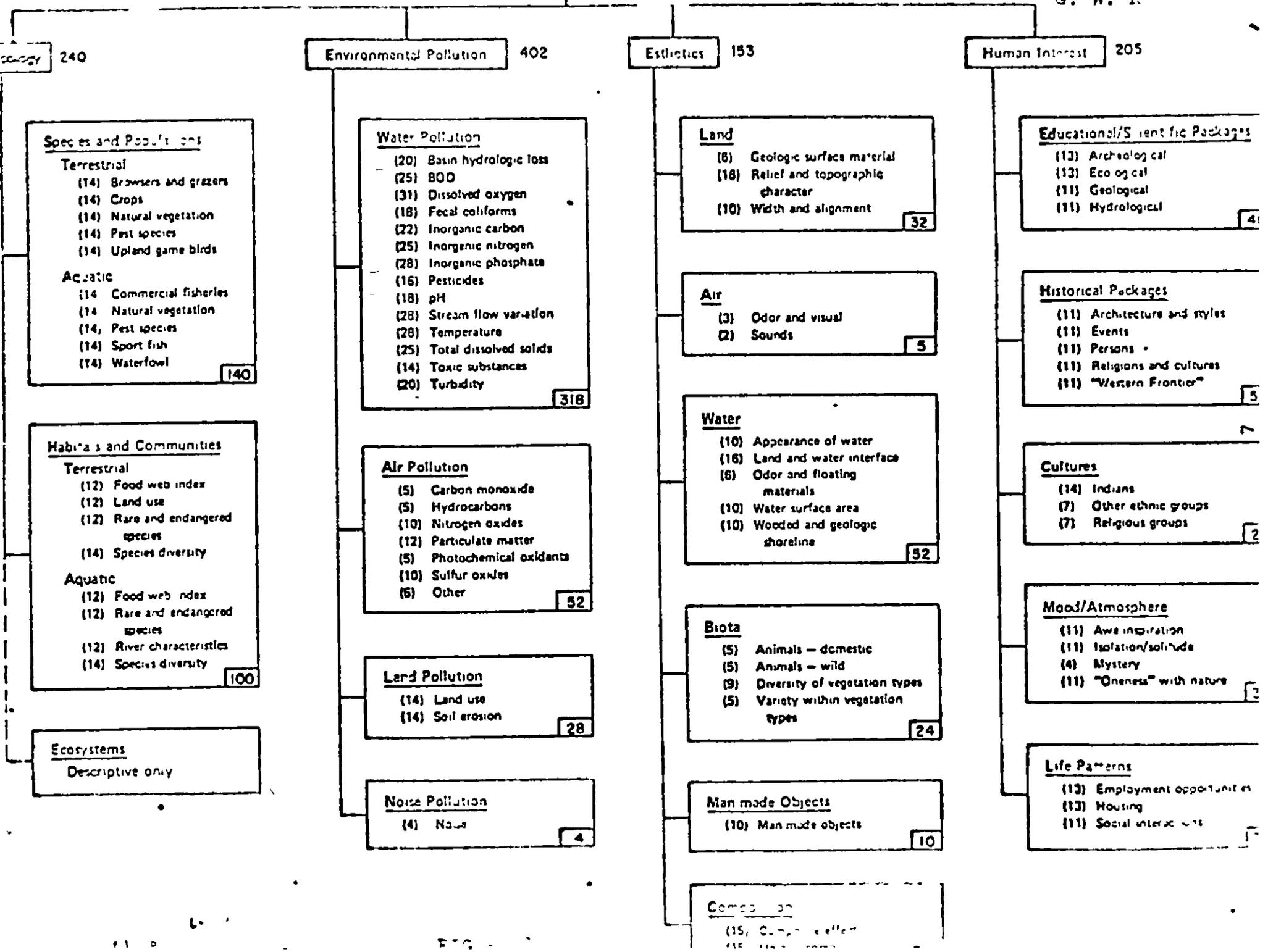
Construction Phase

1. Displacement of people.
2. Noise
3. Soil Erosion and Disturbance of natural drainage.
4. Interference with water table.
5. Water pollution
6. Air pollution (including dust and dirt, and burning of debris).
7. Destruction of or damage to wildlife habitat.
8. Destruction of parks, recreation areas, historic sites.
9. Aesthetic impact of construction activity and destruction of or interference with senic values.
10. Impact of ancillary activities (e.g., disposal of earth, acquisition of gravel and fill).
11. Commitment of resources to construction.
12. Safety hazards.

Operation of Facility -- Direct Impacts

1. Noise
2. Air pollution
3. Water pollution
4. Socio-Economic
5. Aesthetic
6. Effects on animal and plant life (ecology).
7. Demand for energy resources.

Operation of Facility -- Indirect Impacts

1. Contiguous land use.
2. Regional development patterns.
3. Demand for housing and public facilities.
4. Impact on use of nearby environmental amenities (e.g. parks, woodlands, recreation areas).
5. Impact of additional and/or improved transportation into congested areas on those areas.
6. Differential usefulness for different economic and ethnic groups (and resulting problems and solutions).
7. Impact on life styles of increased mobility and other impacts.
8. Impact of improved facility on transportation and related technological

...ology 240

Species and Populations

Terrestrial
- (14) Browsers and grazers
- (14) Crops
- (14) Natural vegetation
- (14) Pest species
- (14) Upland game birds

Aquatic
- (14) Commercial fisheries
- (14) Natural vegetation
- (14) Pest species
- (14) Sport fish
- (14) Waterfowl

140

Habitats and Communities

Terrestrial
- (12) Food web index
- (12) Land use
- (12) Rare and endangered species
- (14) Species diversity

Aquatic
- (12) Food web index
- (12) Rare and endangered species
- (12) River characteristics
- (14) Species diversity

100

Ecosystems

Descriptive only

Environmental Pollution 402

Water Pollution
- (20) Basin hydrologic loss
- (25) BOD
- (31) Dissolved oxygen
- (18) Fecal coliforms
- (22) Inorganic carbon
- (25) Inorganic nitrogen
- (28) Inorganic phosphate
- (16) Pesticides
- (18) pH
- (28) Stream flow variation
- (28) Temperature
- (25) Total dissolved solids
- (14) Toxic substances
- (20) Turbidity

318

Air Pollution
- (5) Carbon monoxide
- (5) Hydrocarbons
- (10) Nitrogen oxides
- (12) Particulate matter
- (5) Photochemical oxidants
- (10) Sulfur oxides
- (5) Other

52

Land Pollution
- (14) Land use
- (14) Soil erosion

28

Noise Pollution
- (4) Noise

4

Esthetics 153

Land
- (6) Geologic surface material
- (16) Relief and topographic character
- (10) Width and alignment

32

Air
- (3) Odor and visual
- (2) Sounds

5

Water
- (10) Appearance of water
- (16) Land and water interface
- (6) Odor and floating materials
- (10) Water surface area
- (10) Wooded and geologic shoreline

52

Biota
- (5) Animals — domestic
- (5) Animals — wild
- (9) Diversity of vegetation types
- (5) Variety within vegetation types

24

Man made Objects
- (10) Man made objects

10

Composition
- (15) Composite effect
- (15) Unique composition

Human Interest 205

Educational/Scientific Packages
- (13) Archeological
- (13) Ecological
- (11) Geological
- (11) Hydrological

4

Historical Packages
- (11) Architecture and styles
- (11) Events
- (11) Persons
- (11) Religions and cultures
- (11) "Western Frontier"

5

Cultures
- (14) Indians
- (7) Other ethnic groups
- (7) Religious groups

2

Mood/Atmosphere
- (11) Awe inspiration
- (11) Isolation/solitude
- (4) Mystery
- (11) "Oneness" with nature

3

Life Patterns
- (13) Employment opportunities
- (13) Housing
- (11) Social interactions

1. Overview - Environmental Concerns
               Economic Concerns

   A Balance? For Whom? Where?

2. Equations - (Total Needed)

   Energy = Pop x Life style + Waste

   Energy = Used Energy + Residuals of Energy

3. Acct. Proc & Eff. -

   $$\frac{Energy}{Time} = \frac{Used^n}{Time} + \frac{Residual^n}{Time}$$

4. Acct. Procedure "A"

   Cross-Impact (Impact vs. Source)

                    Search for Sources

5. Acct. Procedure "B"

                    Search to Min. Residuals

6. Possible Actions

   A. Greater Conversion Eff.

           Examples, Automobile Air Cond.
                     Cusdy/algal control

   B. Reduced Pace

           Examples, Air plane
                     Ship
                     Lighter then Air Ship

           Idea of continuous put through

   C. Reduced #s

           Examples, pop. control
                     Small is beautiful

   D. Beter Distribution in Renewable Resures
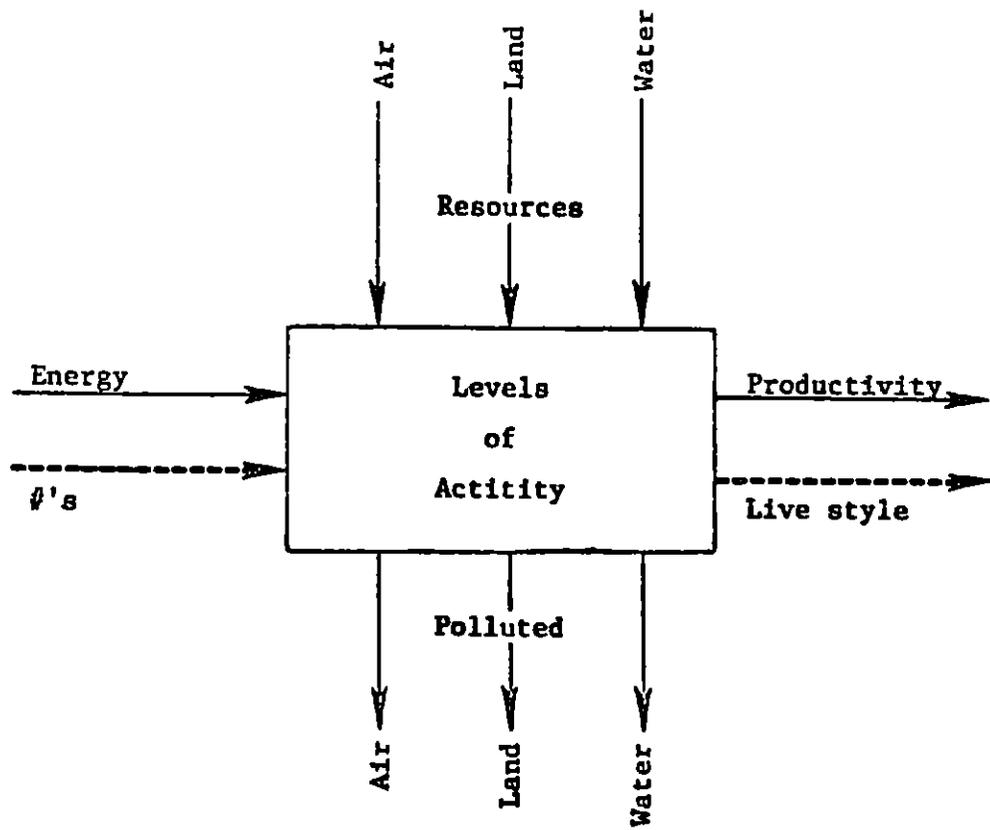
Figure #1

	Ecological	Environmental	Esthetics	Human
Nuclear		●		
Oil	●	●		
Coal	●	●	●	●
Gas				
Tidal	●	●		
Water	●	●		
Wind			●	
Geothermal				

Figure #2
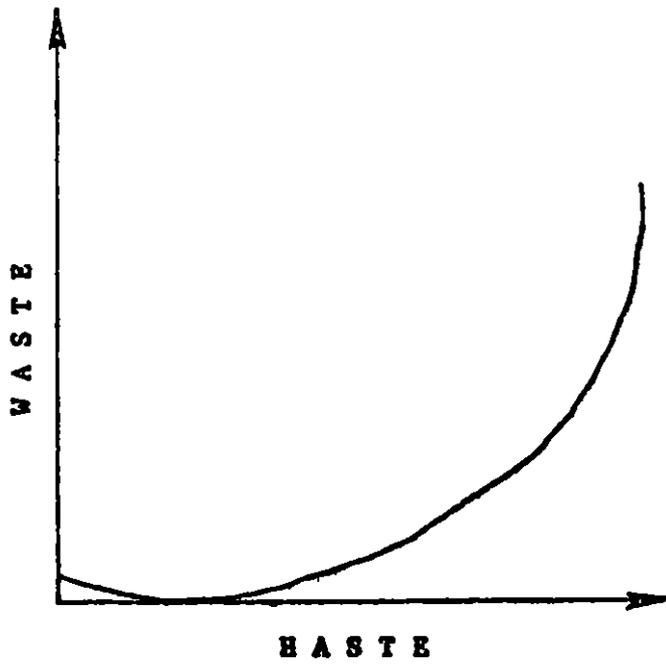
Figure #3

Ecological Example

Waste Disposal- Aqua Culture, Fish,

This

Sewage ⟶ Biodegrade ⟶ Algae ⟶ Minows ⟶ Fish ⟶

⟶ Vascular ⟶⟶⟶ Food
Plants
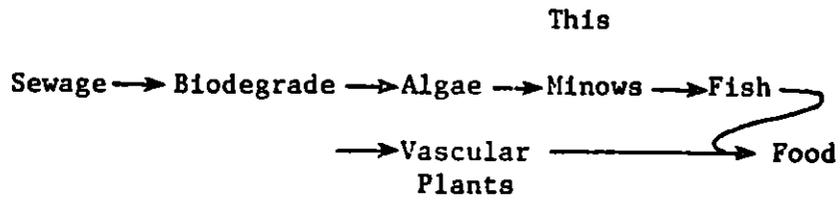
Constrewed by by-products unnatural.

SOCIAL AND DEMOGRAPHIC IMPACTS

I. Categories of impact.

    A. Population changes--size and composition.

    B. Labor force participation.

    C. Displacement of population.

    D. Quality of life of communities.

        1. Community cohesion and compatibility.

        2. Activity patterns (social, cultural, religious, recreational, institutional).

        3. Sociopolitical attitudes and institutions.

        4. Sociocultural symbols.

    E. Welfare of individuals.

        1. Public services.

        2. Mobility.

        3. Safety.

        4. Sense of well-being.

II. Assessment methodogies in general.

    A. Intrinsic "softness".

    B. Dependence on demography, sociology, political science, psychology, and geography.

    C. Use of comparative case study approaches.

III. Assessing population changes.

    A. Begin with economic effects (employment).

    B. Multiply change in employment by ratio between population size and employed persons (may be done by category of employment).

C. Consider sources of additional employed persons or destinations of departed persons: migration estimates, by total number and with reference to D and E below.

D. Consider age and sex distributions as well as population totals; compare all estimates with projections derived from population growth models.

E. If appropriate, consider changes in composition of population by cultural group (ethnic identification, area of origin).

F. Question of the scale of analysis.

IV. Assessing labor force participation.

A. Consider changes in (1) the proportion of a demographic group who are part of the labor force (women, youths, elderly, certain cultural groups; and (2) the proportion of the labor force represented by each cultural and age group.

B. This is based mainly on population change assessments (II above), but it is also desirable to refer to similar cases that have occurred in the past at other locations.

V. Displacement of population.

A. Will the proposed activity require land that is presently the location of residences? How many people are involved? What are their age groups and cultural groups?

B. Where will the people go? What is needed to overcome undesirable social costs from this?

VI. Quality of life of communities.

A. Identify effects on community cohesion of population displacement and the creation of barriers to movement.

B. Assess effects of inmigration or outmigration on community compatibility and stability, including the introduction of new ideas, objects, and modes of behavior.

C. Analyze current activity patterns--social, cultural, religious, recreational, institutional--and consider any effects of the proposed activity on them.

D. Consider effects of the activity on sociopolitical attitudes and institutions: structures of influence; the strength, cohesion, and points of view of interest groups; patterns of political activity in the area.

E. Consider the possible destruction, change, or creation of symbols of society and culture (see the lecture on Historical and Aesthetic Impacts).

VII. The Welfare of individuals.

A. Assess changes in supplies and demands for services such as health care, schools, water, sanitation, and law enforcement.

B. Consider improved or lessened mobility due to transportation improvements, congestion, etc.

C. Assess the potential of injuries or deaths due to accidents related to the proposed activity.

D. Consider the effect of the proposed activity on the sense of well-being among the local population: attitudes toward increased urbanization, job changes, inmigration of people from different areas, etc.

ENVIRONMENTAL ELEMENTS IN AN ECOLOGICAL UNIT

Ecology can be simply defined as the study of the interrelationship between the living organisms (human included) and their environment. In a human-oriented ecological unit, the whole complex of environmental elements, inclusive of all physical, biological and human aspects, are fully functional, interacting as well as maintaining system equilibrium. The physical environment is initially a given from nature and thus in most cases performs in a dorminant role in an ecological unit. Physical together with biological components constitute the natural environment in which man lives, utilizing nature-provided resources. In the human aspects of an ecological unit, major compartments likely to be considered include demographic, economic, social and cultural areas. Demographic elements show the statistics of human population with respect to the size, density, distribution and mobility, etc. Economic activity involves the process of producing commodities by making use of resources and the consumption of these commodities Social considerations concern the well-being and welfare of man in the environment in which he interacts. And, finally, cultural regards pertain to the psychological well-being of man

Listed below are the major environmental categories operative in an ecological unit along with their performance measurements. Neither one is intended to be exhaustive.

I. Natural Environment

   A. Physical
      1. Terrestrial: tundra, taiga, temperate forest, grassland, chaparral, desert, tropical forest, savanna, etc. The terrestrial physical environment can be described in terms of the following.
         a. topography
         b. area
         c. soil type
         d   mineral
         e   temperature ⎤
         f   rainfall ⎯⎯⎦ climatology
         g. air quality
      2. Aquatic freshwater, brackish, marine, etc. The descriptive parameters of aquatic environment include the following.
         a. area
         b. depth
         c. stream pattern
         d. slope of channel
         e. channel capacity
         f. flows
         g. sedimentation
         h. water quality

   B. Biological
      1. Botanical natural vegetation, crops, etc.
      2. Zoological: fish, amphibian, water fowl, game bird, mammals, etc. They can be described in terms of the following.
         a. population
         b   productivity
         c. wildlife habitat
         d   food web index
         e. species diversity
         f. rare and endangered species

II. Human Aspects

   A. Demographic population statistics, characteristics
      The performance measurements consist of the following
      1   Population
      2   Age-sex-race distribution
      3   Population density
      4. Population growth
      5. Migration rate
      6   Mobility
      7. Family structure

   B. Economic agriculture, mining, forestry, fisheries, energy, water supply, land use, recreation, etc. The potential indicators include the following.

1. GNP
2. Income per capita
3. Income by major source
4. Occupational distribution
5. Labor force - employment, unemployment, nonworker-worker ratio
6. Major businesses and industries
7. Farms and farm value
8. Area and value of each type of land use

C. Social politics, institutional relationships, public safety, communication, transportation, housing, health care, leisure, etc
They can be measured in terms of the following.
   1. Electoral participation
   2. Fire and police protection
   3. Legal justice
   4. Mileage of highways and streets
   5. Number and type of housing units
   6. Number of persons per doctor ratio
   7 Birth and death rates and infant mortality
   8. Health care facilities
   9. Number of recreational facilities and attendance

D. Cultural ethics, religion, education, history, humanities, aesthetics, etc   Potential commensurable items are as follows
   1. Moral values, standards
   2. Religious affiliations
   3. Average educational attainment
   4. Historical background and trends
   5. Achievements in humanities
   6. Aesthetic values, levels

I. The concept of the "carrying capacity" of an area: relation
    to level of technology, accessibility.

II. Proposed uses of the concept.

    A. Population redistribution.

    B. Tax policy--"potential productivity," increases in the
    productivity of rural areas through progressive taxation.

    C. Others.

III. The effect of a change in carrying capacity because a change
    in technology.

    A. The process of shifting from one form of land use to another.

    B. The example of a "NUPLEX" on an arid seacoast.

IV. Measuring carrying capacity: is it possible?

    A. Ambiguity of the concept.

    B. Political sensitivity of the measurements: the role of
    disinterested parties.

    C. The relativity of the measurements.

    D. The possible utility of remote sensing.

V. Environmental impact assessment and carrying capacity.

COMPARING ENERGY SUPPLY ALTERNATIVES:

A Case Study of Environmental Impact Assessment In The United States

I.   Federally-supported energy supply facilities in the United States:
     legal requirements for impact statements.

II. Characterizing the impacts of a proposed facility.

   A.   Identifying "trajectories".

   B.   Estimating environmental residuals, economic costs,
        environmental efficiencies.

   C.   The "Matrix of Environmental Residuals for Energy Systems"
        (MERES) data system.

III. Comparing alternatives for achieving the same ends.

   A.   Data summaries by trajectory and location.

   B.   Methodologies for comparison.

   C.   The "Energy Model Data Base" (EMDB) system, including the
        Energy Reference System.

IV. Limitations and problems.

   A.   Converting residuals to impacts (a site-specific problem).

   B.   Data shortages (especially economic data.)

   C.   Inattention to social impacts and regional economic impacts.

V.   Current directions.

   A.   Expanding the data base, especially for non-fossil energy
        sources.

   B.   Further work on optimization modeling, including spatial
        allocation models.

   C.   Base-line studies and other preliminary assessments in
        preparation for evaluating social and economic impacts.

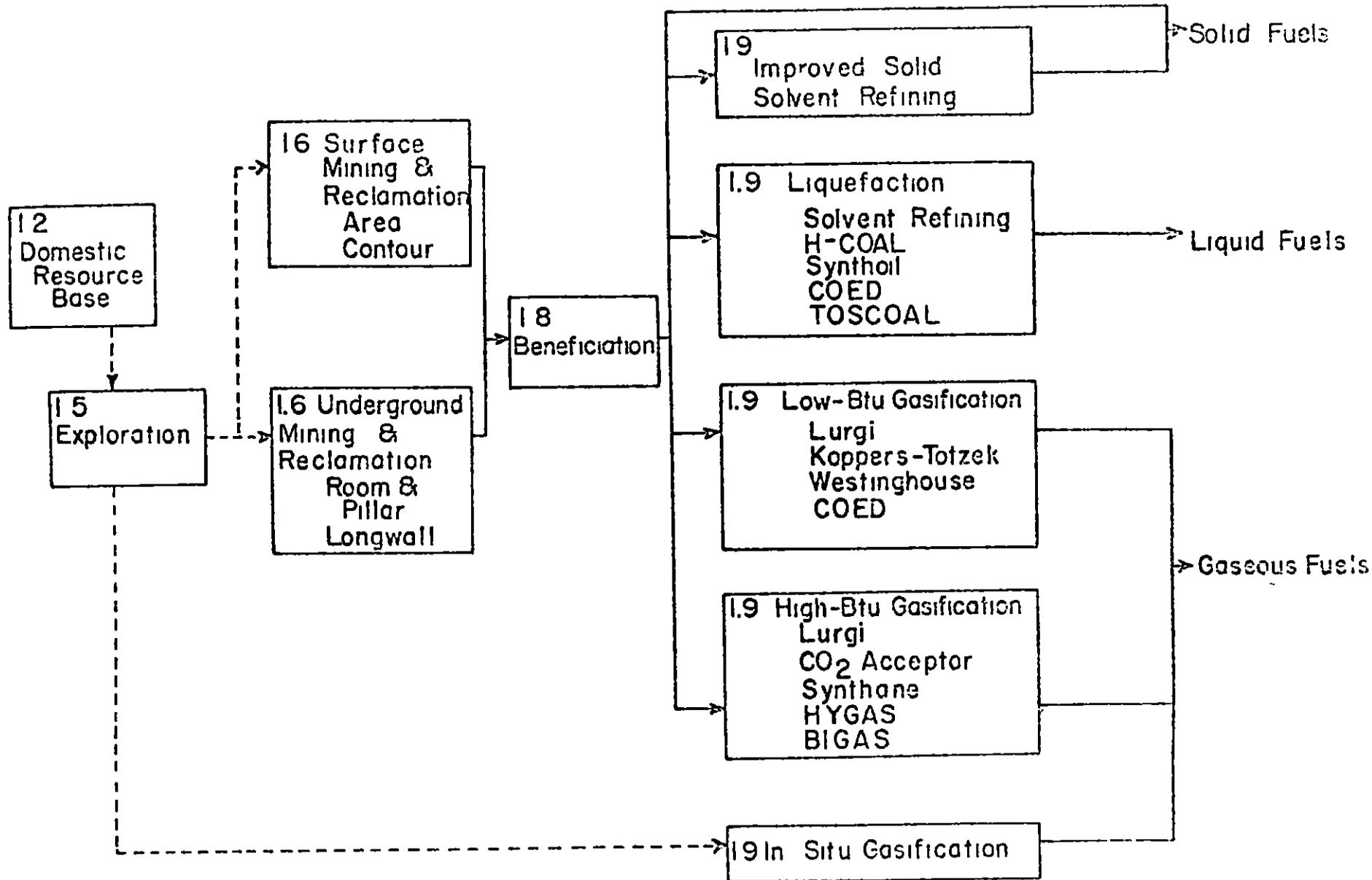D. Increased attention to input requirements as well as output
    impacts.

Figure 2
National Energy System
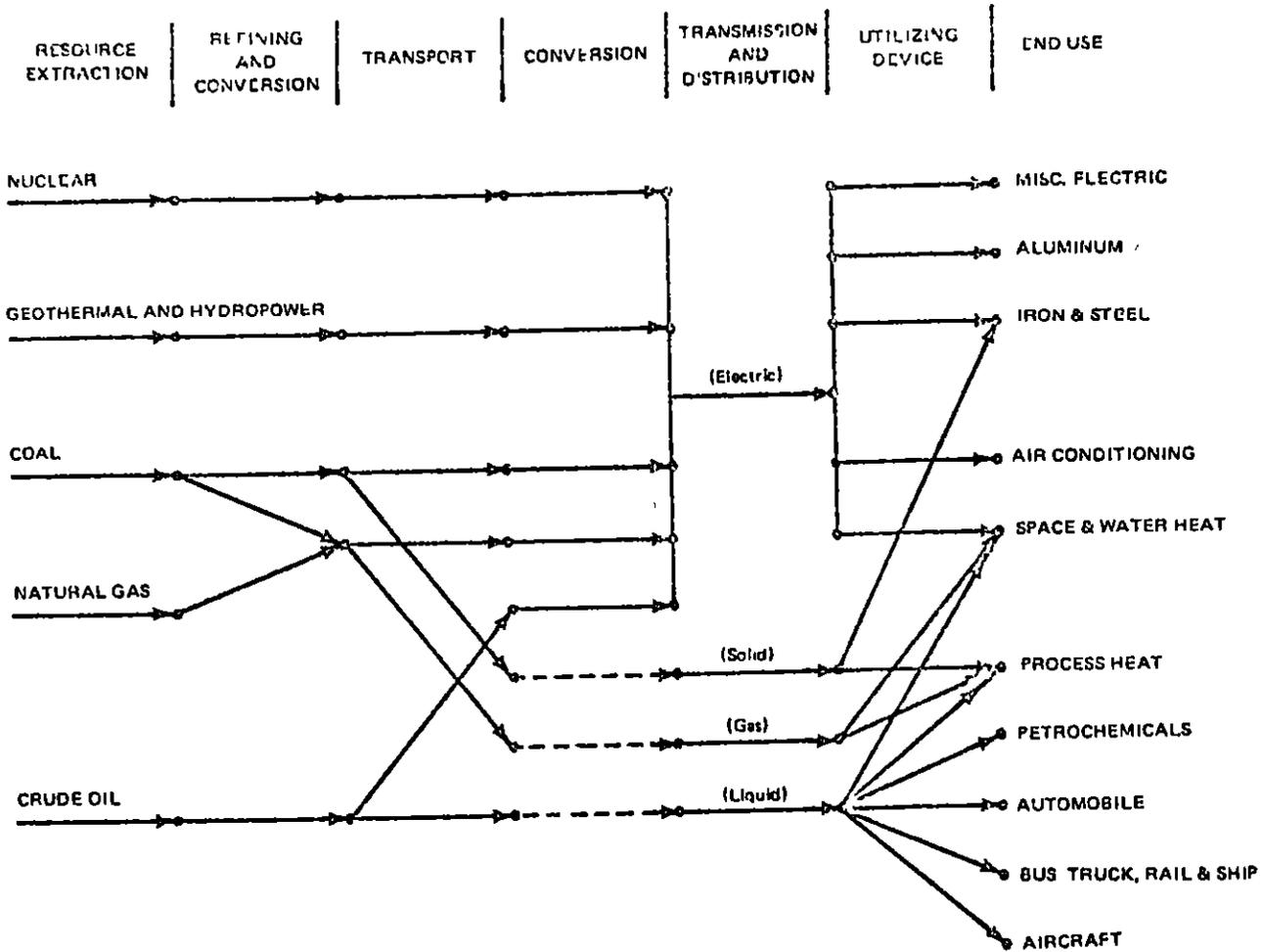
Source Brookhaven National Laboratory Energy/Environmental Data Group, 1974,
The Reference Energy System and Associated Data Base."

technologies and trajectories that are operational now
All types of energy resources, extraction processes,
refining, conversion, transportation, and end uses are
included The horizontal line beginning with the word
"coal" represents the entire coal supply system shown in
Figure 1

For each process included in the system, MERES
contains coefficients which estimate its environmental
impacts, its efficiency, and its investment and operating
costs In a sense, the environmental impacts, given in
terms of water pollutants, air pollutants, solid waste, and
land use requirements, are all residuals — that is, all are
unwanted byproducts of energy processes Although the
Council recognizes that residuals are not a measure of
the effects of pollutants, residuals may be used as
indicators of these effects Estimates are also presented
for occupational health and the potential for large-scale
disaster at the process level

Figure 1.   Coal Resource Development

Boxes and labels in the figure:

- 12 Domestic Resource Base
- 15 Exploration
- 16 Surface Mining & Reclamation Area Contour
- 1.6 Underground Mining & Reclamation Room & Pillar Longwall
- 18 Beneficiation
- 19 Improved Solid Solvent Refining → Solid Fuels
- 1.9 Liquefaction Solvent Refining H-COAL Synthoil COED TOSCOAL → Liquid Fuels
- 1.9 Low-Btu Gasification Lurgi Koppers-Totzek Westinghouse COED
- 1.9 High-Btu Gasification Lurgi CO_2 Acceptor Synthane HYGAS BIGAS
- 19 In Situ Gasification → Gaseous Fuels

——— Involves   Transportation   1.7 and 110 Transportation Lines

------ Does Not Involve   Transportation

Table 4
Residuals of a Synthane High Btu Gasification Plant
(2 62 x 10^11 Btu/day output)

Activity/Process	Water Pollutants (Tons/d yr)			Air Pollutants (Tons/day)							Solid (tons/day)	Land			Occupational Health			Limits	
	Thermal 10^9 Btu		Total	Particulates	NO$_x$	SO$_2$	Hydrocarbons	CO	Aldehydes	Tot Pollutants		Acres	Inv acred (ac or r/yr)	Trem (acres)					
Mining and Reclamation Strip 15° or less	NA	NA	0	443	544	0398	0544	.332	00883	142	388	15	0	747	481	11	272	0	0
Within or near Mine Transportation Trucking	NA	NA	0	00471	134	00074	0134	0900	C0103	254	0	100	0	57	0	5 0	128	0	0
Reclamation Crushing and Sizing	NA	0	0	0	0	0	0	0	0	0	177	55	0	100	0	645	20	0	0
Processing/Conversion Synthane	0	0	0	6 73	596	4 93	989	33	183	750	1980	330	0	749	U	U	U	28	.0411
Transportation Feeder Pipeline	NA	NA	NA	0	802	0	638	0	0	847	0	U	0	2410	0	117	273	0	0
Subtotal	0	0	0	7 8	61	504	648	372	193	162	2370	U	0	4160	U	U	U	16	0041
Transportation Transmission Pipeline	NA	NA	NA	0	276	0	0	0	0	278	0	U	0	8980	.004	136	319	0	0
TOTAL	0	0	0	7 18	888	804	648	372	103	190	2370	U	0	13100	U	U	U	25	0041

NA = not applicable   NC = not considered   U = unknown

[a] For a synthane facility processing 22,550 tons per day, feeder and transmission pipelines require 62 5 feet of right-of-way and a 76 acre compressor station every 187 miles.

[b] m=averaged total land impact for the life of the facility

[c] MERES data for gathering pipelines is used

[d] Subtotals is for all residuals that will be produced at or near the mine. Transmission pipeline residuals will be spread over the length of the pipeline. Certain residuals as for pumping stations for example could be localized.

Source University of Oklahoma, The Science and Public Policy Program, 1975 Energy Alternatives A Comparative Analysis Table 14 1 p 14-6.

Table 4 quantifies certain pollutants and the health and safety factors expected with the hypothetical plant Similar anaylses of other alternatives are the basis of Figure 6, which shows the nitrous oxides generated by the hypothetical project and the alternatives This comparison can be broken down further (Figure 7) to show, for example, where in the trajectory these impacts occur—at or near the mine or extraction site, along the transportation corridor, or at the demand center *
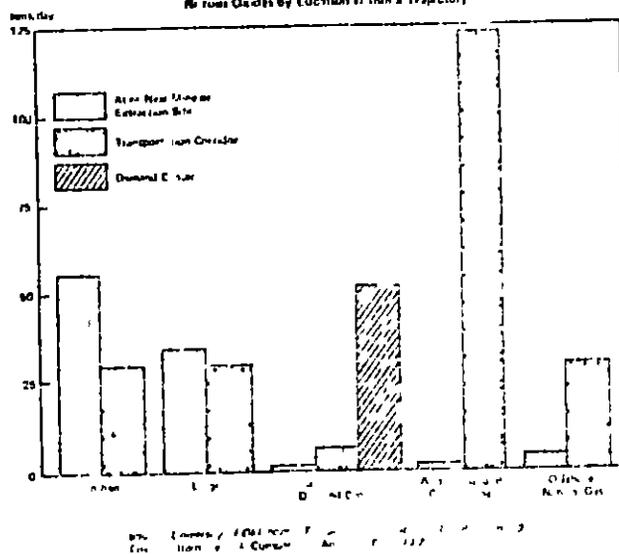
*All data in MERES pertain only to effects generated in the United States, for imported oil or liquefied natural gas the analysis takes no account of impacts produced abroad
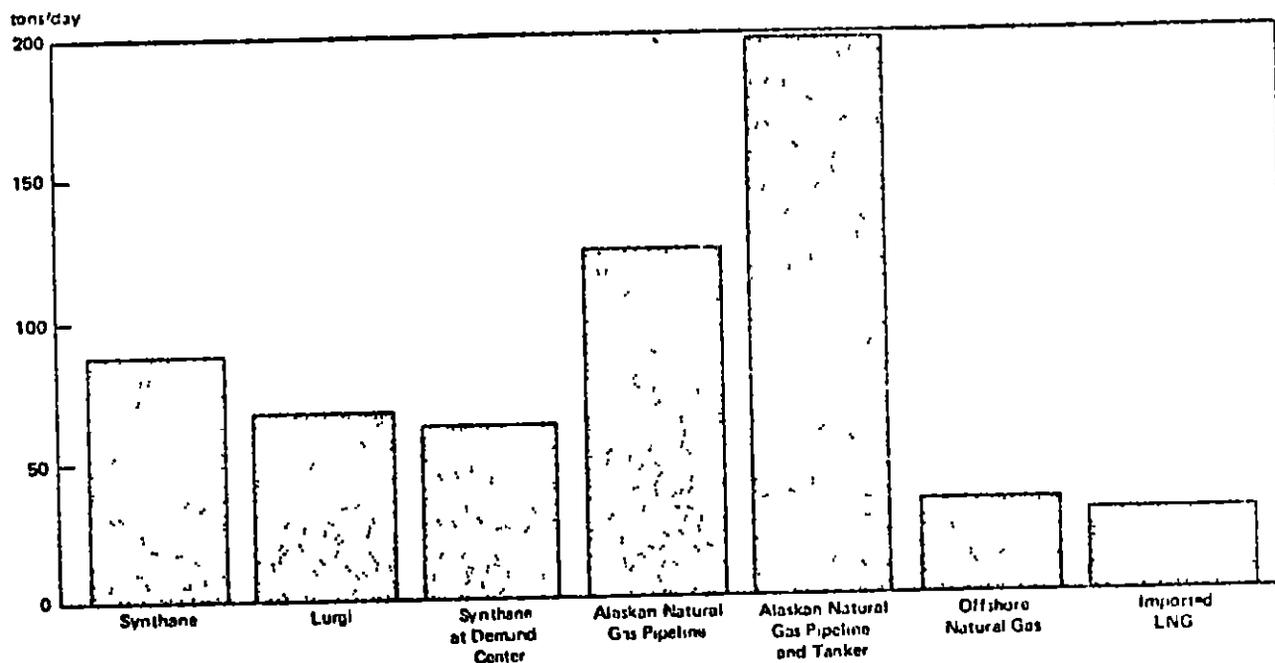
67

Figure 6
Nitrous Oxides by Trajectory

Source University of Oklahoma The Science and Public Policy Program 1975,
Energy Alternatives A Comparative Analysis, Figure 14-5 p. 14-22
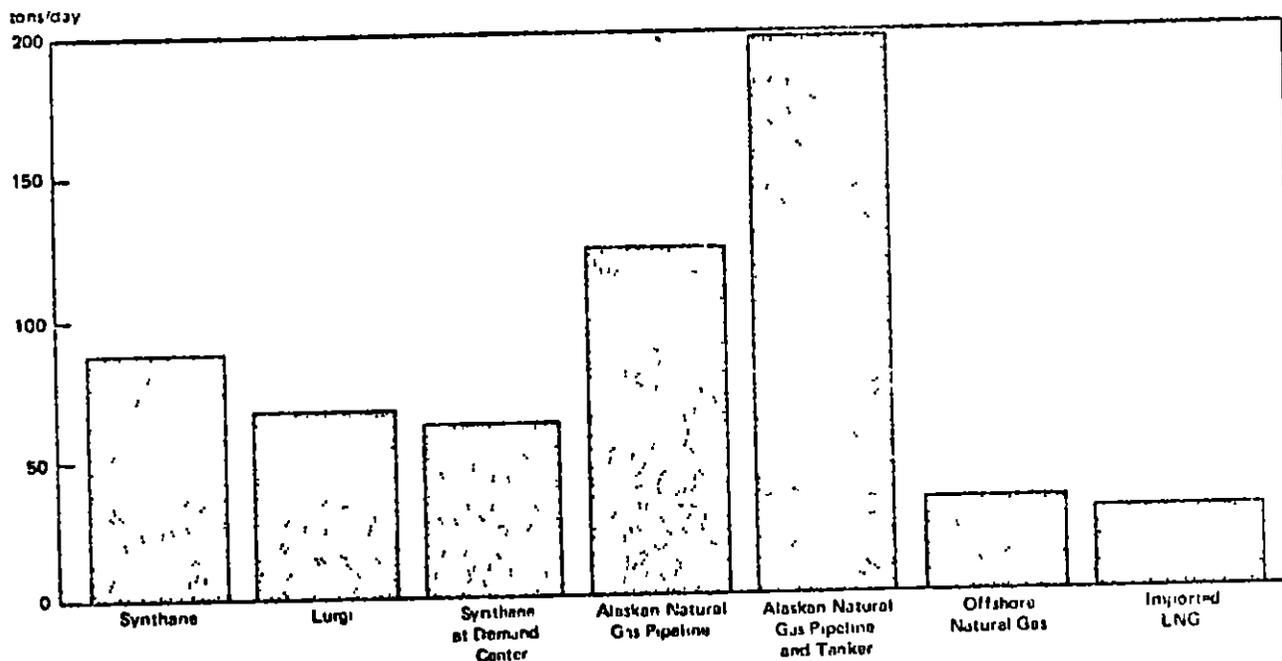

Figure 7
Nitrous Oxides by Location Within a Trajectory

ECONOMIC IMPACTS

I.   Categories of impact.

   A.   Employment/labor force.

   B.   Income.

   C.   Economic structure of area.

   D.   Interregional competiton.

   E.   Demand for/use of resources (including land).

   F.   Costs and prices of goods and services.

   G.   Infrastructure and other technological externalities.

   H.   Tax base.

II. Assessment in general.

   A.   Project what would happen in future with no new activity.

   B.   Project economic impacts of several alternative activities.

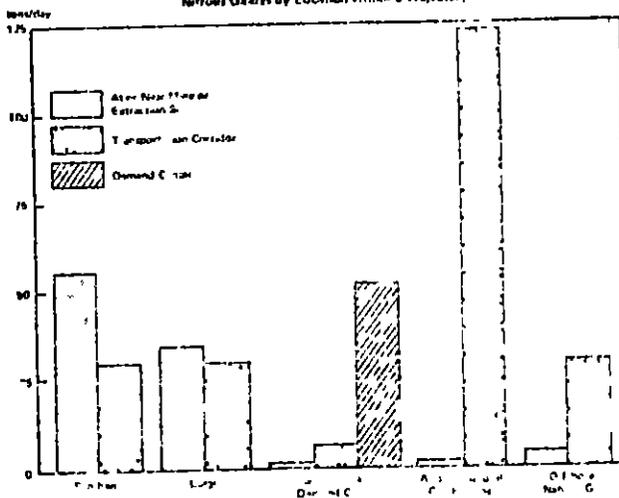   C.   Compare the results and evaluate the proposed activity.

III. Principal assessment methodologies.

   A.   "Economic base," the "multiplier", and export base models of
        regional growth.

   B.   Input-output analysis.

   C.   Location theory.

   D.   Spatial equilibrium theory.

   E.   Interaction theory.

   F.   Cost-benefit analysis.

   G.   Economic forecasting.

Figure 6
Nitrous Oxides by Trajectory

tons/day

Source University of Oklahoma The Science and Public Policy Program 1975
Energy Alternatives A Comparative Analysis, Figure 14-5 p. 14-22.

Figure 7
Nitrous Oxides by Location Within a Trajectory

68

ECONOMIC IMPACTS

I.   Categories of impact.

   A. Employment/labor force.

   B. Income.

   C. Economic structure of area.

   D. Interregional competiton.

   E. Demand for/use of resources (including land).

   F. Costs and prices of goods and services.

   G. Infrastructure and other technological externalities.

   H. Tax base.

II. Assessment in general.

   A. Project what would happen in future with no new activity.

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III. Principal assessment methodologies.

   A. "Economic base," the "multiplier", and export base models of
       regional growth.

   B. Input-output analysis.

   C. Location theory.

   D. Spatial equilibrium theory.

   E. Interaction theory.

   F. Cost-benefit analysis.

   G. Economic forecasting.

IV. Special problems.

    A. Shortage of data.

    B. Definition of the "impact area".

    C. Changes in the value of the currency unit.

    D. Externalities, especially the potential effect of the proposed activity as a locational attraction for other activities.

    E. Remembering the possible economic effects of physical impacts.

Table 2 1   Philadelphia Region Input Output Flows Table, 1968
(Based on 1959 Coefficients Partly Updated to 1965 and
1968 Sector Outputs in Millions of 1968 Dollars)

PURCHASING SECTOR / PRODUCING	1 Agriculture Fisheries	2 Food Processing & Kindred Prod	3 Textile Mill Prod	4 Apparel	5 Lumber & Wood Prod	6 Furniture & Fixtures	7 Paper & Allied Prod	8 Printing & Publishing	9 Chemicals & Chemical Prod	10 Petroleum Refining & Prod	11 Rubber & Misc Plastic Prod	12 Leather & Leather Prod	13 Stone Clay & Glass Prod	14 Primary Metals	15 Fabricated Metal Prod	16 Machinery (excl Electric)	17 Electric Machinery	18 Motor Vehicles	19 Misc Manufacturing	20 Prof & Scientific Equip
1 Agriculture Fisheries	61	382	20	1	•	–	–	–		–		–	2A	•			–	–	–	10	–
2 Food Processing & Kindred Prod	14	668	•		–	–	1	–	70	1		6	•	–		11	–	–	8	–
3 Textile M ll Prod		•	166	245	–	2	2	1	12	–	13	1	1	•			1	•	2	2
4 Apparel	•		–	40	–	–	•					•	1	•					–	–
5 Lumber & Wood Prod	1	1	•	•	19	9	•	•		–		•	•	2	2	4	3	2	9	17	•
6 Furniture & Fixtures	–	–	–	•		4	–	–	–	–		–	–	–	–	•	27	2	–	•
7 Paper & Allied Prod		106	5	7	3	4	205	157	35	16	6	•	7	1	12	3	15	3	11	4
8 Printing & Publishing	•	10	–	1	1	•	2	46	16	2	1		1	1	1	6	4	11	2	1
9 Chemicals & Chemical Prod	3	12	16	1	2	4	21	11	351	59	51	1	10	10	75	3	11	4	19	6
10 Petroleum Ref ning & Prod	3	10	3	1	•	•	5	1	91	119	5		6	23	4	8	2	2	2	1
11 Rubber & Misc Plastic Prod		•	•	1	–	2	11		3	1	3		1	•	8	5	13	13	3	2
12 Leather & Leather Prod	–	–	•	1	–	–	–	–	–	–		5	–	–	–	–	–	–	–	•
13 Stone Clay & Glass Prod	•	17	2	–	1	1	–	–	19	2	–		19	73	3	4	19	4	15	2
14 Primary Metals	–	•	•	•		25	1	4	3	7	3	•	7	186	266	251	105	188	17	29
15 Fabricated Metal Prod.	1	46		1	7	9	•		1	16	51	1		4	2	15	67	42	5	7
16 Machinery (excl Electric)	1		•	•				7	2		1	•		20	6	87	17	92	8	7
17 Electric Machinery	–	•		–	1	–	•		–	–	–			•	•	78	317	39	2	77
18 Motor Vehicles	•	•	–	–	–	–	–	•		3	–		–	–	–	1	1	100	–	–
19 Misc Manufacturing	•			4	6	•	•	•	2	–	–	•	1	–	–	•	•	•	4	2
20 Professional & Scientific Equip	–	•		–	–	–	•	2	–	–	–	–	–	–	2	7	6	4	•	10
21 Coal Gas & Electric Power	1	18	5	4	1	2	12	4	25	31	4		7	24	8	12	10	7	3	2
22 Transportation	•	•	•	–	–	–	•		–	–	–		•	•		•	•	–	–	–
23 Wholesale Trade	–	–	1	–	•	•	•		3	–		–	•	30	3	–	–	–	–	–
24 Retail Trade (excl Eating Places)	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–
25 Communications	1	7	2	3	•	1	2	11	8	3	2	•	1	5	4	8	6	4	2	2
26 Finance & Insurance	1	16	6	8	1	1	6	7	19	15	3		4	12	7	9	6	4	5	7
27 Real Estate & Rentals		1			•	•	•	1	1					•	•	1	1	•		•
28 Business Serv (incl Advertising)	2	65	7	9		2	8	35	135	38	11	1	5	43	10	15	25	15	6	4
29 Hotel Personal & Repair Serv	1	2	2	3		•	1	1	1	–	1		1	1	1	2	2		•	•
30 Automobile Repair		13			1	•	1	1	2	2		•	1	1	1	1	•			
31 Private Household Serv	–		–	–	–	–		–		–		–	1	–	–	–	–		–	
32 Amusement & Recreational Serv	–	–			–	•	•	•	–				•	–		•	•		–	–
33 Eating & Drinking Places	–				–	–	–	–						–	–				–	
34 Misc Industries			–	–	–	–	–		8	–	–		14	1		•	•		1	–
35 Nonprofit Orgs			–	–		–	–			–	–		–	–		–	–		–	
36 Construction	2	11	•	1			3	3	2	3	•	•	1	9	1	3	2	2	1	
37 Research & Development	–			–	–	–			3	1	–			1		2		1		
38 Medical Health & Hospital Serv	–	–	–	–	–	–	–		–	–	–		–	–	–	•	–	–	–	–
39 Elem Sec & Higher Edu	•		–	–	–	–	–	–	–	•	–		•		•	–	–	–	–	–
40 Local Gov t	1	11	10	14	1	3	11	10	25	25	15		5	1	1	16	29	15	4	5
41 Private Households	16	680	149	249	1	4	112	241	899	185	123	11	97	93	76	92	533	42	3	123
42 Imported	1	11	71	193	9		116	51	4	72	55	6	51	3	11	13	702	4	1	
43 Imports (Non competitive)	4	55	56	14	1	3	7	19	116	745	101		20	215	9	12	55	1	4	
44 Gov t Taxes Fed & St	1	42	12	12	1		29	41	103	64	19	1	11	91	73	52	50		4	15
45 Profits & Dividend	41	36	•	9	1	2	25	23	68	60	18		10	79	21	40	42	41	8	5
46 Capital & Repair	15	56	1	7	1	4	73	12	91	181	12		15	41	18	17	3	15	4	6
47 Loan & Misc Charges	–	15	2	5			18	5	80	17	5		1	71	11	11	20	1		

THE NATIONAL ENVIRONMENTAL POLICY ACT AND ITS IMPLEMENTATION.

The past several years have been characterized by passage of major Federal legislation dealing with the environment, including specific legislation on control of water and air pollution.(1,2)   Perhaps the most significant legislation is the National Environmental Policy Act (NEPA) of 1969 (PL91-190), which became effective on January 1, 1970. The Act was the first signed in the decade of the 1970's.(3) The thrust of this Act, as well as subsequent Executive Orders, Council on Environmental Quality (CEQ) guidelines, and numerous Federal agency procedures, is to insure that balanced decision making occurs in the total public interest . (4) Project planning and decision-making is to include the integrated consideration of technical, economic, environmental, social and other factors. Prior to NEPA, technical and economic factors dominated the decison-making process. A copy of the National Environmental Policy Act is contained in Appendix A.

TERMINOLOGY

New terminology has arisen in conjunction with the process of complying with the requirements of NEPA. Three of the most significant new terms are environmental inventory, environmental assessment, and environmental impact statement.

(a) Environmental Inventory

Environmental inventory represents a complete description of the

environment as it exists in an area where a particular proposed action is being considered. The inventory is compiled from a checklist of descriptors for the physical, biological and cultural environment. The physical environment includes such major items as geology, topography, surface and groundwater resources, water quality, air quality, and climatology. The biological environment includes a consideration of the flora and fauna of the area, including species of trees, grasses, fish, herpetofauna, birds, and mammals. Specific reference must be made to any rare and/or endangered plant or animal species. General biological features such as species diversity and overall ecosystem stability should also be presented. Items in the cultural environment section include human population trends and population distributions, historic and archeological sites, and economic indicators of human welfare.

The environmental inventory serves as the basis for evaluating the potential impacts, both benefical and adverse, of a proposed action on the environment. It is included in an impact statement in the section referred to as "description of the existing environment", or "description of the environmental setting without the project". (5) Development of the inventory represents an initial step in the environmental impact assessment process.

(b) Environmental Assessment

The environmental assessment represents the key step in meeting the requirements of NEPA. In essence, it represents an attempt to evaluate the consequences of a proposed action on each of the descriptors utilized in the environmental inventory.

The essential steps in an environmental impact assessment are:

1. Prediction of the anticipated change in an environmental descriptor.

2. Determination of the magnitude or scale of the particular change.

3. Application of an importance or significance factor to the change.

Many of the current assessment approaches embody the steps of prediction, scaling, and significance interpretation, although the methods use many terms to describe these particular steps.

The scientific validity of the technology available for the prediction of impacts varies depending upon the particular environmental descriptor. For example, there has been extensive research and sound scientific methods developed for prediction of air quality impacts (6), at least with regard to anticipated concentration levels of pollutants in the ambient air; however, impacts on flora or fauna as a result of the calculated concentration levels are less quantifiable. Thus it is possible to utilize sound technology for some impact predictions, whereas other predictions must be primarily based on professional judgment.

In order to accomplish an environmental assessment, as well as to prepare an inventory and write an impact statement, it is necessary that the approach utilized be interdisciplinary, systematic and reproducible. Requirements for a interdisciplinary approach indicate that the environment must be considered in its broadest sense, thus the input of persons trained in a number of technical fields needs to be included. (7) The disciplines to be utilized in a specific environmental assessment must be oriented to the unique features of the proposed action and the environmental setting, however, at a minimum it is necessary to have input from a physical scientist or engineer, a biologist, and a person who can address cultural

-3-

and socio-economic impacts. Requirements for a systematic and reproducible approach indicate that a degree of organization and uniformity be utilized in the assessment process. In this regard, several assessment methodologies have been developed since 1970, (8,9) and these will be discussed in more detail later.

(c) Environmental Impact Statement

The environmental impact statement is a document written in the format as specified by NEPA, CEQ guidelines and specific agency guidelines The environmental impact statement represents a summary of the environmental inventory and the findings of the environmental assessment. Environmental impact statments are also referred to as "environmental statements", "impact statements", "environmental impact reports", or "102 statements". (10) The term "102 statement" refers to the section in NEPA which deline-ates requirements for the preparation of an environmental impact statement.

There are two categories of environmental impact statements, namely, draft statements and final statements. The draft statement is the document prepared by an agency proposing an action, it is circulated for review and comment to other Federal agencies, state and local agencies, and public and private interest groups. Specific requirements with regard to timing of review are identified in the CEQ guidelines, and the 1973 CEQ guidelines are included as Appendix B. The final statement is the draft statement modified to include a discussion of problems and objections raised by re-viewers The final statement must be on file with CEQ for at least a thirty-day period prior to initiation of construction on a project.

NATIONAL ENVIRONMENTAL POLICY ACT

The Act is divided into two basic parts; Title I which is a declaration

of a national environmental policy, and Title II which established the Council on Environmental Quality. The national goals as specified in Section 101 of the Act are as follows (4)

1. Fulfill the responsibilities of each generation as a trustee of the environment for succeeding generations,

2. Assure for all Americans safe, healthful, productive and aesthetically and culturally pleasing surroundings,

3. Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences,

4. Preserve important historic, cultural, and natural aspects of our national heritage and maintain, where possible, an environment which supports diversity and variety of individual choice,

5. Acheive a balance between population and resource use which will permit high standards of living and a wide sharing of lifes aminities; and

6. Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

Section 102 of NEPA has three primary parts related to the environmental impact assessment process. Part A specifies that all agencies of the Federal government shall utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and environmental design arts in planning and in decision-making which may have an impact on man's environment. Part B requires agencies to identify and develop methods and procedures which will insure that presently unquantified environmental aminities and values may be given appropriate consideration in decision-making along with economic and technical considerations. This part has provided impetus for the development of several environmental assessment methods. Part C indicates the necessity for preparing environmental statements, and identifies basic items

to be included. This particular part indicates that agencies should include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement that covers five major areas. (4) These areas are.

1. The environmental impact of the proposed action,

2. Any adverse environmental effects which cannot be avoided should the proposal be implemented,

3. Alternatives to the proposed action,

4. The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

5. Any irreversible and irretrivable commitments of resources which would be involved in the proposed action should it be implemented.

The requirement for preparing an environmental impact statement was not a part of the original proposed legislation which subsequently became NEPA. (11) Detailed histories of the legislative background of NEPA have been presented by Andrews and Yannacone and Cohen. (12, 13) The Section 102 requirements were added late in the legislative review process, just prior to final action on the part of Congress This particular requirement has been called the "action-forcing mechanism" of NEPA. (14) This indicates that agencies must take the action to prepare a draft statement which is then subject to review and critique by other Federal agencies as well as state and local governmental and private groups. It is an understatement to say that the NEPA requirements for preparing impact statements have been controversial. (15, 16). Many court cases have resulted from this section of NEPA (17, 18, 19, 20) Perhaps one of the problems with NEPA is that the Act did not contain a provision for insuring compliance.

One section of NEPA which is received very little attention is Section 103. It requires that all agencies review their present statutory authority, administrative regulations, and current policies and procedures for the purpose of determining whether there are any deficiencies or inconsistencies therein which prohibit full compliance with the purposes and provisions of NEPA. Very few written responses have been recorded with regard to action taken with conjunction with Section 103. (11,22)

MAJOR ACTIONS SIGNIFICANTLY AFFECTING THE QUALITY OF THE HUMAN ENVIRONMENT

Section 102 of NEPA requires that environmental statements be prepared for "major Federal actions significantly affecting the quality of the human environment". The Corps of Engineers use the anacronym MASAQHE for this phrase. Definitions were not included in NEPA for what constituted a major action or what constituted a significant affect on the quality of the human environment Concern with these definitions is relevant since the preparation of an environmental impact statement requires both human and economic resources. (23) One of the occurrences since the passage of NEPA has been the preparation of impact statements on projects that perhaps should not require much attention; namely, installation of traffic control signals and minor roadway resurfacing work. On the other hand, many major actions of the Federal government, such as peacetime military activities and space activities, have not had environmental impact statements filed.

To attempt to define a "major action significantly affecting the quality of the human environment" involves many quantitative and qualitative considerations The simplest way of defining a major action is to

compare a predicted impact with an environmental quality standard for a given parameter. It is possible to do this for many substances found in air and water, for example, suspended particulates in the atmosphere and dissolved oxygen in water. However, there are many environmental parameters for which only subjective standards are available; for example, scenic vistas and archeological sites. Agencies can best define MASAQHE by project type, indicating that certain projects require impact statements because they are major actions, and others do not because they are minor actions. The Federal Highway Administration has developed guidelines of this type. (24) Major actions include highway sections entirely or generally on new location, major upgrading of an existing highway section which requires extensive right-of-way acquisition and construction. Highway sections which may have a significant affect on the quality of the human environment include those:

1. That are likely to have a significantly adverse impact on natural ecological, cultural, or scenic resources of national, State or local significance.

2. That are likely to be highly controversial regarding relocation housing resources.

3. That divide or disrupt an established community or disrupt orderly, planned development or is inconsistent with plans or goals that have been adopted by the community in which the project is located or causes increased congestion.

4. Which involve inconsistency with any national, State or local standard relating to the environment, has a significantly detrimental impact on air or water quality or on ambient noise levels for adjoining areas; involves a possibility of contamination of a public water supply system, or affects groundwater, flooding, erosion or sedimentation.

Negative declarations can be prepared on the following types of highway improvement actions since they are not likely to have significant impacts:

1. Signing, marking, signalization and railroad protective devices.

2. Acquisition of scenic easements.

3. Modernization of an existing highway by resurfacing; less than lane width widening, adding shoulders; auxillary lanes for localized purposes.

4. Correcting substandard curves.

5. Reconstruction of existing stream crossings where stream channels are not affected.

6. Reconstruction of existing highway/highway or highway/ railroad separations.

7. Reconstruction of existing intersections including channelization.

8. Reconstruction of existing roadbed, including minor widening, shoulders and additional right-of-way.

9. Rural two-lane highways on new or existing location which are found to be generally environmentally acceptable to the public and local, State, and Federal officials.

BASIC CONTENTS OF AN IMPACT STATEMENT

Section 102, Part C, of NEPA identified five points that needed to be discussed in an environmental impact statement. The first one is to describe "the environmental impact of the proposed action". In the early years of the preparation of impact statements, attention was primarily focused on the negative or detrimental impacts associated with a given proposed action. To be complete, both beneficial and detrimental impacts should be delineated. The basic thrust of NEPA is that it is a "full disclosure law", implying that both the positive and negative ramifications

-9-

of a given proposed action be explored in complete detail. (25) In addition to the consideration of these matters, attention must also be directed toward the primary and secondary impacts associated with a proposed action. (5) Primary and secondary impacts are also referred to as direct and indirect consequences. Table 1 includes a partial listing of the direct and indirect impacts of a sewage treatment plant, with only adverse impacts being identified. (26) In general, agencies have developed methods and precedures to somewhat respond to direct impacts, both beneficial and adverse. However, the major impact of a project is often from secondary or even tertiary effects, and these are much more difficult to assess due to the dearth of predictive techniques available.

The second section required by NEPA is an identification of "any adverse environmental effects which cannot be avoided should the proposal be implemented". If a thorough approach has been utilized in describing the environmental impact of the proposed action, this section should basically be an abstract of the negative impacts, both direct and indirect, of the proposed action. New information is not included in this section.

The third section focuses on a discussion of "alternatives to the proposed action". This section has caused a great deal of difficulty, and many court cases have resulted from inadequate treatment of this section by the proposing agency.(17,18,19,20) Kennedy and Hanshaw (27) reported on an analysis of the alternatives sections of 200 randomly selected environmental statements from several agencies. Of the 127 actions which listed adverse environmental effects, a total of 214 alternatives were listed, all of which were rejected. 130 were rejected for economic reasons, 47 for environmental reasons (that is, the alternative would do more harm than the

TABLE I.   PARTIAL LISTING OF DIRECT AND INDIRECT IMPACTS OF
           SEWAGE TREATMENT PLANT

ADVERSE IMPACTS/Direct

	Primary Effects	Secondary Effects	Tertiary Effects
Short Term	Erode soil during construction	Degrade aquatic habitat of stream	Decrease fisheries
Long Term	Periodic releases of noxious gases	Decrease surrounding property values	Change socio-economic composition of neighborhood*

ADVERSE IMPACTS/Indirect

Short term	Construction employment	Temporary housing	Does not occur
Long term	Permit-encourage residential development within service area*	Increase traffic on local streets	Traffic congestion, noise, smog

Note.   Impacts are described for illustrative purposes only,
a complete matrix for a sewage plant would contain many more
impacts within each of the respective cells of the matrix.   A
separate matrix could be constructed for beneficial impacts.

*Irreversible impact.

proposed action), and 37 because of engineering problems. The basic impli-
cation of the alternatives section is that the alternatives for the proposed
action should be compared on a common basis, presumably their relative or
absolute environmental impact. (28)   One alternative which must be dis-
cussed is the no action, or no project alternative. (5)   This alternative
requires the proposing agency to predict what the future environment will
be without the project, and it serves as the basis upon which impacts of
the proposed action can be considered.   Concern regarding alternatives
originally arose in conjunction with the question of the retroactivity of
NEPA, and two well-known court cases which evolved around this point in-
clude the Gillham Reservoir in southwestern Arkansas, and the Cross-
Florida barge canal. (17)   One consideration in the alternatives section
should be an evaluation of the alternatives through a public participation
program. (5)

The fourth item is a description of "the relationship between local
short-term uses of man's environment and the maintenance and enhancement
of long-term productivity".   This section is based on the principle that
each generation should serve as trustee of the environment for succeeding
generations, therefore, attention must be addressed to the question of
whether or not options for future use of the environment are being elimi-
nated by the particular proposed action.   In a pragmatic sense, many impact
statements have described the impacts associated with the construction and
operational phases of a proposed action in this section, considering the
construction phase to be short-term and the operational phase to be long-term.

The last section is a discussion of "any irreversible and irretrievable
commitments of resources which would be involved in the proposed action

should it be implemented". Semantic difficulties are encountered with the

terms irreversible and irretrievable. Again from a practical standpoint,

most impact statements focus attention on possible changes in land usage

as a result of a proposed action, loss of cultural features such as arche-

ological or historic sites, preclusion of development of underground

mineral resources, loss of habitat for plants and animals, loss or impact

on rare and endangered plants and/or animals, material required for pro-

ject construction, energy usage required during project utilization, and

even the human and monetary expenditures involved.

COUNCIL ON ENVIRONMENTAL QUALITY GUIDELINES

Section II of NEPA established the Council on Environmental Quality.

The responsibilities of CEQ in relationship to the impact statement pro-

cess includes serving as a central repository for final environmental

impact statements, preparation of general guidelines applicable to all

Federal agencies in conjunction with their compliance with NEPA, review

of draft environmental impact statements (particularly for controversial

projects), and the development of comparative analyses on the impact

statement process. Federal agencies can request consultation and guidance

from CEQ in conjunction with NEPA compliance or the preparation of agency

procedures and guidelines.

The Council on Environmental Quality published guidelines for the

preparation of environmental impact statements on April 23, 1971, and

August 1, 1973. (29, 5)

The guidelines issued in 1971 gave coordination to the impact state-

ment process, particularly with regard to review of draft environmental

impact statements. (29) Two new sections were added to the five basic

points specified to be included in an impact statement by NEPA, namely,

a section describing the proposed action, and a section oriented to a

discussion of problems and objections raised by reviewers. The first new

section preceeds the basic five points, and the latter follows. A list

of Federal agencies with responsibility for various areas of environmental

quality was included.

The CEQ guidelines of August 1, 1973 called for the addition of two

more new sections in an impact statement, plus an expansion of a previous-

ly required section. (5) The initial section called for in an impact state-

ment became a description of the proposed action as well as a description

of the existing environment. One new section is on the relationship of

the proposed action to existing land use plans, policies and controls in

the affected area. This requires a discussion of how the proposed action

may conform or conflict with the objectives and specific terms of any

Federal, state or local land use matters, either approved or proposed.

In addition, land use plans developed in response to the requirements of

the Clean Air Act or the Federal Water Pollution Control Act Amendments

of 1972 should also be specified. (2, 1) The second new section calls for

an indication of what other interest and considerations of Federal policy

are thought to offset the adverse environmental effects of the proposed

action. This section is oriented to a discussion of other decision factors

that the agency feels tend to counterbalance any adverse environmental

affects. Agencies that prepare cost-benefit analyses of proposed actions

should summarize these analyses in this section. Where non-environmental

costs and benefits are part of the basis for decision, it is important that

the agency specify the importance of these elements in the decision. (30)

-14-

THE ROLE OF THE ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) was established in December, 1970 as the environmental regulatory agency of the nation. (31) It is not the chief administrative agency for environmental impact statements. The EPA serves to review environmental impact statements prepared by others, particularly with regard to water pollution, air pollution, solid waste management, noise, radiation and pesticides. Each statement reviewed is assigned a rating based on the proposed action and the environmental impact statement document itself. (32)   The EPA system of rating other agency actions is as follows

1. Project Rating (LO, ER, or EU).

   LO (Lack of Objections). EPA has no objections to the pro-
   posed action as described in the draft impact statement or
   suggests only minor changes in the proposed action.

   ER (Environmental Reservations). EPA has reservations con-
   cerning the environmental effects of certain aspects of the
   proposed action   EPA believes that further study of sug-
   gested alternatives or modifications is required and has
   asked the originating Federal agency to reassess these
   aspects.

   EU (Environmentally Unsatisfactory). EPA believes that the
   proposed action is unsatisfactory because of its potentially
   harmful effect on the environment. Furthermore, the Agency
   believes that the potential safeguards which might be uti-
   lized may not adequately protect the environment from hazards
   arising from this action. The Agency recommends that alter-
   natives to the action be analyzed further (including the
   possibility of no action at all)

2. Adequacy of Document (1, 2, or 3).

   Category 1 (Adequate) The draft impact statement ade-
   quately sets forth the environmental impact of the pro-
   posed project or action as well as alternatives reasonably
   available to the project or action.

   Category 2 (Insufficient Information). EPA believes that
   the draft impact statement does not contain sufficient

information to assess fully the environmental impact of
the proposed project or action. However, from the infor-
mation submitted, the Agency is able to make a preliminary
determination of the impact on the environment. EPA has
requested that the originator provide the information
that was not included in the draft statement.

Category 3 (Inadequate). EPA believes that the draft im-
pact statement does not adequately assess the environmental
impact of the proposed project or action, or that the state-
ment inadequately analyzes reasonably available alternatives.
The Agency has requested more information and analysis con-
cerning the potential environmental hazards and has asked
that substantial revision be made to the impact statement.

No rating of the proposed action is made if the EIS is assigned a

Category 3 rating because a basis does not generally exist on which to

make a determination about the environmental impact of the proposed project.

All "3" and "EU" ratings on draft impact statements must be cleared at the

EPA Headquarters level in order to double check that all such ratings are

consistent with policies and practices followed by EPA on a nationwide scale.

The originating agency is notified of the assigned ratings at the time a com-

ment letter is sent. EPA also notifies the CEQ of its comments on all "3"

or "EU" projects so that the Council can begin to follow up the project at

an early stage in its development.

Although EPA does not have official responsibility with regard to im-

pact statements acceptance or rejection, the review of this agency is

critical, and the procurement of a satisfactory evaluation of the impact

statement and the proposed action is very necessary.

The EPA has also developed guidelines and procedures for the prepara-

tion of impact statements associated with their proposed actions. (33)

The Federal Water Pollution Control Act Amendments of 1972 exempted EPA

from the NEPA requirement of preparing impact statements in activities

leading to the setting of new source pollution standards, effluent limita-tions, guidelines for water quality standards and establishing "best practicable" and "best available" treatment standards. (15, 34)

With regard to agency procedures, most Federal agencies have developed guidelines for the environmental impact statement process. Moore (35) has indicated that each agency's NEPA-response regulations should:

1. Identify those agency actions requiring an environmental impact statement.

2. Designate officials responsible for the statements.

3. Specify the general methods for obtaining information required in preparation of the statement.

4. Indicate the required content of an environmental impact statement.

5. Designate the appropriate time prior to decision to seek comments of other agencies.

6. Establish patterns for consulting with and taking into account comments of other agencies.

7. Describe the mechanism through which statements are to be made available to the public.

8. Provide for timely public announcement of plans and pro-grams with environmental impact.

STATUS REPORT ON ENVIRONMENTAL IMPACT STATEMENTS

Many problems have arisen with regard to the environmental impact statement process. Three major categories of problems were identified in the Third Annual CEQ report (36), including procedural concerns, questions regarding the content of environmental impact statements, and the role of the Council on Environmental Quality. Procedural problems, at least in the period from 1970 through 1972, dealt largely with the following types of questions·

1. What actions require impact statements?

2. What are the impact statement requirements for actions initiated or authorized prior to NEPA inactment?

3. Can impact statements be prepared for programs rather then individual projects?

4. Which agency is responsible for preparing the impact statement for a proposed action involving multiple agencies?

5. What are the requirements for the review and comment process?

6. Do existing agencies with environmental regulatory activities have to prepare environmental impact statements?

7. Does an environmental impact statement have to be available for normal agency public hearings?

The required content of environmental impact statements has largely been clarified by the development and issuance of CEQ and agency guidelines. The basic contents at the current time should cover the items included in the CEQ guidelines of August 1, 1973. It is the duty of the proposing agency to consider opposing views to the particular proposed action and to discuss alternatives to that particular action. If the agency proceeds inspite of the possible adverse and environmental affects, the environmental impact statement should clearly identify the other interests that justify this action

The role of CEQ includes serving in an advisory capacity to Federal agencies and the President, issuing guidelines for implementing Section 102 of NEPA, and identifying significant recurring substantive problems in the impact statement process.

Several comparative critiques of selected environmental impact statements were prepared in the initial years of the existence of NEPA. Ray (37) reported on major areas requiring improvement after reviewing about 250

impact statements from many agencies. The following major points
were noted:

1. Agencies are not fully considering and applying the poli-
   cies expressed in all applicable local, state and Federal
   laws.

2. Both primary and secondary impacts need to be delineated.

3. Alternatives should be discussed in sufficient detail so as
   to not foreclose choices other than the action proposed.

4. The cumulative effects of several time-phased segments of
   a major action on future choices should be presented.

5. Environmental considerations should not be limited to the
   framework of strict legislative mandates.

6. Proper attention and full consideration of all public and
   private reviews, comments, statements and testimonies
   have not been adequately documented in all statements.

7. The preparation of environmental statements has not really
   been used as an effective vehicle for proper land use
   planning.

In 1972, the Government Accounting Office (GAO) reported on a review

of seven Federal agencies' response to NEPA requirements. (38) The agencies

included the Corps of Engineers (Civil Functions), Forest Service, Soil

Conservation Service, Department of Housing and Urban Development, Bureau

of Reclamation, Federal Aviation Administration and Federal Highway Admin-

istration. The GAO indicated that improvements were needed in the following

areas.

1. Environmental impact statements as integral parts of decision-
   making processes.

2. Actions requiring environmental impact statements and the
   ranges of impacts which should be considered.

3. Public participation in environmental assessment.

4. Methods for obtaining views of Federal, state and local agencies.

A second study by GAO examined the adequacy of six impact statements. (39) Three common problems associated with these statements were inadequate discussion of, and support for, the identified environmental impacts; inadequate treatment of reviewing agencies' comments on environmental impacts; and inadequate consideration of alternatives and their environmental impacts. The first and last of the three problems were also noted in an analysis of the review of 395 environmental impact statements recieved in 1972 by Region IV (Atlanta) of the Environmental Protection Agency. (40)

Ortolano and Hill (41) reviewed 234 Corps of Engineers environmental statements prepared through August, 1971. One suggestion was that improvements could be made in the description of impacts by reducing levels of generality, dealing with uncertainty, and identifying the recipients of impacts. Attention was focused on educational needs with regard to basic biological concepts. It was noted that applicable water quality standards should be specified for the potentially impacted area. Finally, mention was made of the desirability of considering the impact of alternative project operating policies.

Pearson reported on a review of 50 environmental impact statements in 1973. (42) It was noted that inadequacies exists in describing the probable (or possible) impacts, especially secondary impacts. Qualitative statements instead of quantitative presentation are often used. Alternatives are not presented in detailed fashion. Impact statements as now prepared represent myopic planning and fragmentation of projects. Impact statements can be a valuable aid in decison making, but they are invariably written after the decisions have been made. Reasons given for the inadequacies are most statements are authored by those with no technical environmental expertise

In a survey of 26 EPA employees responsible for preparing draft and final impact statements at the regional level, Hudson (43) reported an average length of Federal service of 6.5 years, with 1.4 years of experience in impact statement work. The average grade level was GS-11. The average years of formal schooling per respondee was more than 17 but less than 18 years. Fourteen of the 26 respondees had Bachelor degrees in Civil Engineering.

The 1973 CEQ Annual Report (44) identified several more recent trends in the environmental impact statement process. The guidelines issued by CEQ in 1973 indicated that environmental considerations should be included early in the planning process; economic, technical and other factors are to be included along with environmental factors in decision-making; program statements are encouraged; secondary environmental impacts should receive greater emphasis; and public participation is encouraged in the environmental impact assessment process. Developments in the courts also were noted in that early cases dealt primarily with the response of agencies to the spirit and intent of the requirements of NEPA. These cases can be characterized as being basically administrative in scope. More recent litigation has dealt with the technical content of statement, and the cases are related to the substantive areas of impact assessment.

A survey of agency "follow-up" procedures during project implementation was conducted by Hudson during 1973. (45) The issue is who has the responsibility to insure that a project is executed in accordance with the environmental analysis and mitigation measures discussed in the environmental impact statement. From a survey data base of 33 Federal agencies, it was concluded that agencies do recognize that their responsibilities for

-21-

protection extend beyond the mere preparation of an environmental impact statement. However, agencies have not developed adequate policies and procedures, including explicit monitoring and evaluation, to ensure that provisions or conditions contained in their environmental impact statements are subsequently carried out.

There had been about 5,500 impact statements prepared through July 1, 1974. (46) The total includes 2,100 draft statements and 3,400 final statements. Table 2 shows the environmental statements, by project type, filed annually to July 1, 1974. Figure 2 shows the same information in graphical form. The peak year for impact statement filing was 1971, with this representing the first major release of impact statements following the passage of NEPA. The current filing pattern is approximately 1,200 impact statements annually.

Concern is often expressed regarding the cost of impact statement preparation, the time required, and the effect of the impact statement process on agency decision-making. Although data is minimal, some recent studies have provided information regarding cost and time for preparation.

The CEQ has estimated that the entire environmental impact statement process costs $65 million annually. (47) Since about 1,300 statements are released per year, either as draft or final statements, the average cost per statement is $50,000. Hudson (48) reported an average cost of $31,000 for 21 final statements prepared in the southeastern United States; however, this figure does not include expenses associated with agency reviews of impact statements prepared by a different agency. From August, 1971 to July, 1973, the average cost of preparation by the U.S. Navy of an environmental impact statement was $7,300. (49) There was considerable variance in preparation cost, ranging from a minimum of $200 to a maximum of almost $50,000.

TABLE 2   ENVIRONMENTAL IMPACT STATEMENTS FILED ANNUALLY, BY PROJECT TYPE, TO JULY 1, 1974

	1970	1971	1972	1973	1974
ROADS	41	1,123	543	305	150
WATERSHED, FLOOD CONTROL	50	299	127	170	83
ENERGY-RELATED PROJECTS	36	59	128	74	53
AIRPORTS	15	141	119	96	41
NAVIGATION	47	93	83	93	66
PARKS, WILDLIFE REFUGES	2	24	84	111	36
PESTICIDES, HERBICIDES	2	16	26	15	12
TIMBER MANAGEMENT	5	1	26	58	54
ALL OTHERS	117	193	235	226	152

FIGURE 2.

Environmental Impact Statements Filed Annually, by Project Type, to July 1, 1974
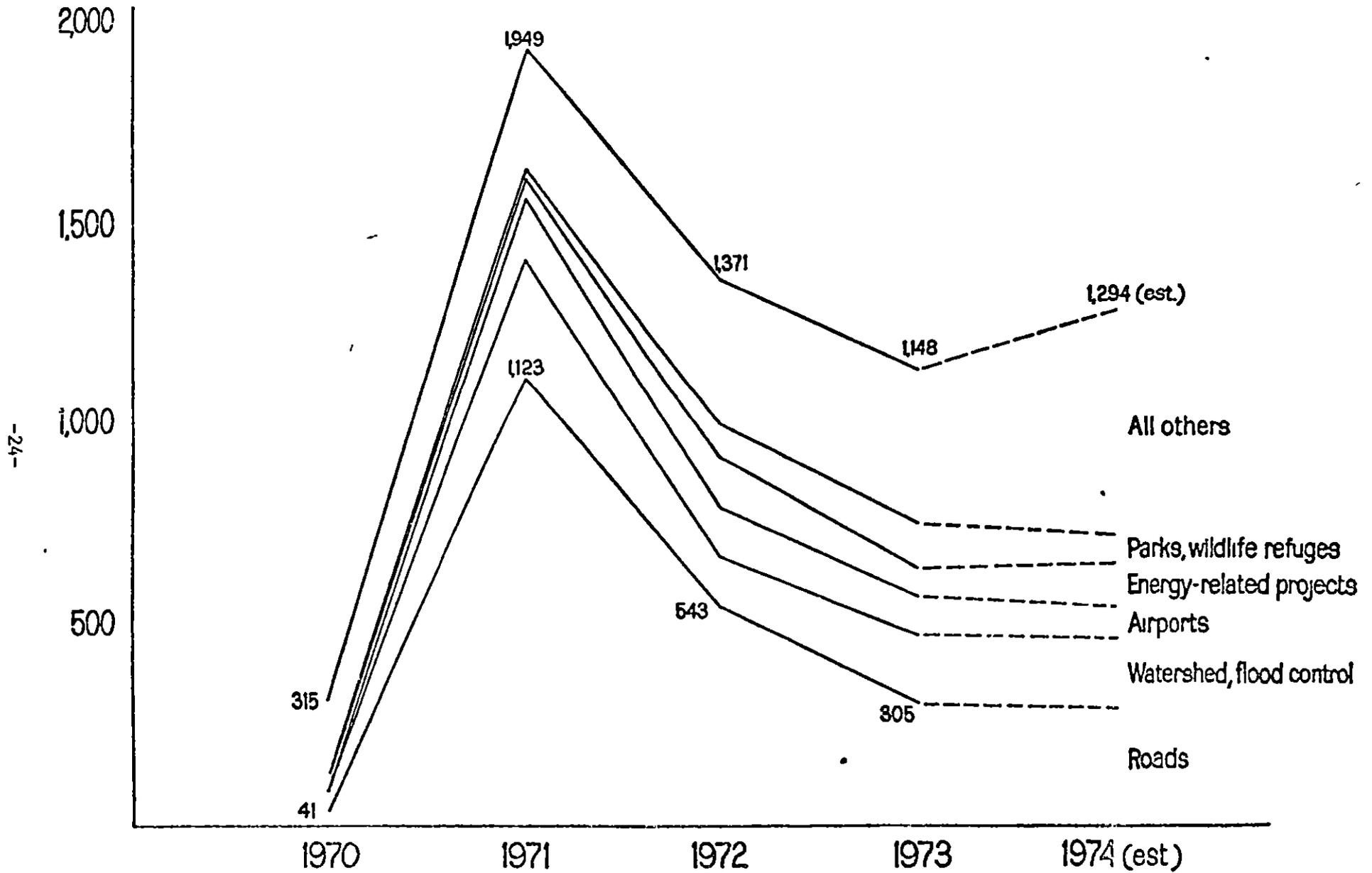
The length of time required for preparation of an environmental impact statement is a function of project size and the point in the planning process when the impact statement is prepared. Some impact statements have been prepared in a matter of weeks, while others have required several years of effort on the part of a number of individuals. Hudson (50) reported that an average of 8 man-months was required per statement prepared by EPA regional offices. Other agencies required 18 man-months per statement. About two-thirds of the time was spent on the draft statement, and one-third on the final statement.

No cost-benefit analysis has ever been made for the environmental impact statement process. However, there are some examples available on the influence of NEPA. The Fourth Annual CEQ report (44) indicated that NEPA had influenced decision-making in the Corps of Engineers since 24 projects have been dropped due to the potential adverse impacts, 44 projects have been temporarily or indefinitely delayed, and 197 projects have been significantly modified. The Corps of Engineers has defined three phases in their environmental impact statement work since January 1, 1970. (51) These phases include a period of interpretation in 1970, a procedural phase in 1971 and 1972, and an integrated planning phase since 1972. The period of interpretation included considerable discussion on requirements, writing of impact statements on back-logged projects, and development of written procedures and requirements. During the procedural phase emphasis was placed on adhering to the letter of the law, and voluminous impact statements were prepared and many court cases evolved. The integrated planning phase places emphasis on fulfilling not just the letter of the law, but also the intent of the law. In this regard, Corps procedures are now

-25-

evolving which insure that the environmental impact statment process will be accomplished early in the planning process for a given project.

STATE ENVIRONMENTAL POLICY ACTS

Beginning in 1970, several states adopted legislation equivalent to NEPA at the state level. (52) The chronological order of development is shown in Table 3. (53) As of November 1973, 16 states plus Puerto Rico had passed state environmental policy acts or their equivalent. Seven other states had attempted passage of such acts and had been unsuccessful. At least 20 other states are considering passage of environmental policity acts. (54) State environmental policy acts are basically patterned after NEPA but are applicable to state funds for proposed actions. The requirements of the state acts do not replace the environmental impact statement process as required by the National Environmental Policy Act.

The private sector is obligated to provide environmental impact statements under rather broad circumstances in California, Montana, and Puerto Rico. (55) The Indiana law precludes state agencies from requiring an environmental statement from a licensee prior to issuance of a permit or license.

FUTURE TRENDS IN THE ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

The environmental impact assessment process is becoming an integral part of the planning process for Federal agencies within the United States. The process is being accomplished at the intial stages of project planning as opposed to an "after-the-fact" statement prepared in accordance with the letter of the law of NEPA. Future trends indicate a focus on regional

TABLE 3: CHRONOLOGICAL ORDER OF STATE ENVIRONMENTAL
POLICY ACT PASSAGE

State	Date
Puerto Rico	June 1970
California	1970
Montana	March 1971
New Mexico	April 1971
Washington	August 1971
Hawaii (1)	August 1971
Wisconsin	1971
North Carolina	1971
Michigan (1)	September 1971
Indiana	1972
Texas (2)	March 1972
Virginia	April 1972
Massachusetts	July 1972
Connecticut (1)	October 1972
Maryland	April 1973
Minnesota	May 1973
New Jersey (1)	October 1973

(1) Executive Order or Directive.

(2) Interagency Council on Natural Resources and
Environment policy statement.

-27-

12'

impacts, greater public involvement, more impact statements from the
private sector, and more court cases dealing with the substantive issues
of environmental impact assessment. It is possible that detailed require-
ments for separate impact statements will be altered in the future in
response to degree that environmental impact assessment becomes a part of
project planning documentation. (56)

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121

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Environmental Impact Assessment

Methodologies

by

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The basic requirements of Parts A and B of Section 102 in the

National Environmental Policy Act are that agencies ahould use systematic

and interdisciplinary approaches, and that they should develop methods

and procedures which will insure that presently unquantified environmental

amenities and values may be given appropriate consideration in decision

making along with economic and technical considerations (1) This

discussion is oriented to various impact assessment methodologies de-

veloped in response to these requirements. An impact is any change in

the physical-chemical, biological,cultural, and/or socio-economic environ-

mental system which can be attributed to the activities of man relative

to the alternatives for a proposed action under study (2).

I. Introduction

    A. Purposes of Environmental Assessment Methods

        1. Insure that all factors are considered, the environment is

           complex system of physical-chemical, biological, cultural,

           and socio-economic resources.

        2. Provide a means for evaluation of alternatives on the basis

           of environmental impact

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3   Identify where data needs exist, and use this to plan field

    studies if necessary.

4   Minimize impact through feedback, i e , provide a means for

    evaluating the effectiveness of mitigation measures.

5.   Provide information for public participation, should be in

    summary form only

6.   Be in compliance with NEPA.

B.   Comparative Studies of Environmental Impact Assessment Methodologies

    1.   Several studies and papers have recently been accomplished on

       comparisons of methodologies; these include:

       (a)   Dickert in 1972 (3)

       (b)   Drobny and Smith in 1973 (4)

       (c)   Warner in 1973 (5) and

           Warner and Bromley in 1974 (6)

       (d)   Warner and Preston in 1973 (7)

       (e)   Smith in 1974 (8)

    2.   Each of the above include a delineation of selected criteria

       for methodology comparison and grouping, in some instances,

       a comparative evaluation of selected methods in relation to

       the criteria is included The remainder of this discussion

       is oriented to these five studies

    3.   A general bibliography on methods is available. (9).

II.   Dickert in 1972 (3)

A.   Classification of Methods

    1   Classification is based on division into three analytical

       functions

(a) identification

(b) prediction

(c) evaluation

2. Each function has a number of associated tasks as shown in Table 1

3. Methods for identification of environmental impacts can assist in specifying the range of impacts that may occur, including their spatial dimensions and time frame Generally, identification methods may answer questions concerning what the components of the project are and what elements of the environment may be affected by these actions.

4. Predictive methods will define the quantity or spatial dimension of impact on an environmental resource (or resource system) given various specific project actions. Predictive methods thus facilitate making distinctions between various project alternatives in terms of questions concerning "how much?" or "where?" an impact may occur.

5 Methods for evaluation should assist in communicating to the decision maker what the deficiencies (trade-offs) are between possible alternatives or courses of action and the impacts associated with each alternative. Evaluation methods should also provide for determining the groups (facility users or populations) that may be directly or indirectly affected by the project or action

B. Identification Methods

1 Two categories of identification methods are.

-3-

TABLE 1.   Classification of Methodology for Environmental
           Impact Assessment

Identification	Description of the existing environmental system
	Determination of the components of the project
	Definition of the environment modified by the project (including all components of the project)
Prediction	Identification of environmental modifications that may be significant
	Forecasting of the quantity and/or spatial dimensions of change in environment identified
	Estimation of the probability that the impact (environmental change) will occur - time period
Evaluation	Determination of the incidence or costs and benefits to user groups and populations affected by the project
	Specification and comparison of the trade-offs (costs or effects being balanced) between various alternatives

(a) checklists

(b) matrices and networks

2 Checklists are the simplest impact identification methods.

    (a) Checklists that have been developed thus far have taken three basic forms lists of environmental conditions and factors (which may be the basis for an inventory or data collection for a project), lists of project types or actions normally carried out by an agency or jurisdiction that may have a significant effect on the environment (and thus for which the agency or jurisdiction should perform at least a preliminary assessment), and lists of factors or questions aimed at providing definition of the scope of the environmental interactions and inter-relationships to be considered

    (b) The checklist may serve as a means of focusing the attention of the preparer or reviewer on those factors which as a matter of agency policy should be considered in the impact statement

    (c) The basic positive feature of the checklist is its flexibility in including a broad array of environmental considerations in a simple summary format On the other hand, this broad definition of considerations many times is specific neither to the project nor project site area, and thus the format does not focus the preparer or reviewer on the most important environmental impacts for the project being considered One possible improvement for utilizing the checklist format would

-5-

be to develop lists of environmental conditions or factors that are specific to the type of projects normally carried out by an agency.

3   Matrices and networks

(a)   The matrix might be visualized as a two-dimensional checklist and is the first step toward defining inter-relationships systematically. These interrelationships, which may not be obvious when initially assessing a project or the environment in which it is proposed, include, cause-effect relationships (stream chaneli-zation-change in composition of stream biota); relation-ships between various components of the project (cut-fill)-pavement surfacing or configuration), and the relationships between various elements of the environment (vegetation - soils).

(b)   An example of a two-dimensional cause-effect matrix is the Leopold matrix developed for the U.S. Geological Survey. (10)

(c)   Several problems are inherent in the use of the simple two-dimensional matrix methods. Most important, synergistic interactions within the environment may not be represented in the matrix. The matrix does not provide a convenient format in which to explain or assess the often related secondary (or indirect) effects of a project

(d)   Network methods have been devised to try to overcome some of the above problems, two examples are the Sorensen

stepped matrix (11) and the Odum energy diagrams (12).

(e) The Sorensen stepped matrix solves at least a portion of
the display problem, encountered in the two-dimensional
matrix, by combining resource uses (e.g., highways), actions
generated (e g., cut fill), initial and subsequent changes
in environmental conditions (e. g , erosion, increase of
stream suspended load), and effects (e. g., reduction in
fish habitat) into one format.

(f) The Odum energy diagram approach proposes diagramming
flows of energy within a resource system and clearly defining
the quantitative nature of the relationships within the
system (e.g., additive, integrative, multiplication, etc.).
The most interesting work done utilizing this method has
concerned defining relationships within food chains

C. Predictive Methods

1. Prediction involves the application of science in decision-
making.

2. Most guidelines and many suggested methods for assessment do
not address this question at all, and thus we assume that pro-
fessional judgment or intuitive reasoning will be used as
the best available method for forecasting and predicting
significant environmental effects The outcome of this
approach in many environmental impact statements has been
the substitution of generalities and disclaimers for
scientific evidence and facts that would substantiate the

opinions of the statement preparer. (Most EIS reviews are
characterized by this phenomenon.)

3　One of the real drawbacks is the lack of detailed environmental
base line data.

4　Few predictive mathematical models (e.g , simulation) have
been directly applied in environmental impact assessment It
appears that both the deficiency of available data and expertise
of impact statement preparers have contributed to this occurrence.
Quantitative analysis of environmental effects has been limited
in most cases to simple presentation of statistical summaries.
The most frequent use of quantitative data has been in reference
to analogous situations.

5.　The problem of accuracy and reliability of predicted environ-
mental response is only beginning to receive attention in impact
statement preparation. Statistical analysis, confirming confi-
dence in the predicted value, and estimation of the probability
of impact occurrence are both measures that could be attached
value of the predicted impact.

6.　Possibly the most difficult predictive task in impact assessment
is the forcasting of so-called cumulative or growth-inducing
effects.

D　Evaluation Methods
1　Several methods have been developed specifically for evaluation
of alternatives in impact assessment, they include
(a)　Battelle Environmental Evaluation System (13)
(b)　Georgia Optimum Pathway Matrix (14)

2. The major purpose of both of these methods is to produce a
single aggregate index of environmental impact for each of the
alternatives, so that they may be compared.

3. The generalized scaling of values associated with the above
methods assumes that the values derived by the study team
are a true representation of societal values and are not biased
either by the composition of the study group or by the mission
of the agency for which the study was prepared. It is hard
to believe, for example, that many socioeconomic groups
(such as low-income groups) would find the Battelle system,
which assigns over one-third of the possible points to environ-
mental pollution and only 26 points (out of a total 1,000)
to housing and employment opportunities, a good representation
of their values.

4. An evaluation method basically involving a series of public
meetings and attendee-responses to the pros and cons of alterna-
tives is being used by the Seattle District of the Corps of
Engineers (15).

III. Droony and Smith in 1973 (4)

A. Basic Requirements for a Methodology

1. Comprehensive

2. Flexible

3 Detect project-generated impacts

4. Objective

5. Insure input of required expertise

6. Utilize the state of the art

7. Employ explicitly defined criteria

8. Provide for assessment of impact magnitude

9. Provide for overall assessment of total impact

10. Detect environmentally sensitive areas

B. This study Became Basis for Warner Study in 1973, Warner and Bromley in 1974, and Smith in 1974.

IV. Warner in 1973 (5) and Warner and Bromley in 1974 (6)

A. Criteria for Methodology Evaluation

1. Three bases are used·

   (a) technical ecological content (what kind of information is produced?)

   (b) practical applicability (how is the information to be generated?)

   (c) political utility (how and by whom is the information used?)

2. Characteristics of technical ecological content were arrived at by a review of literature on basic tenets of ecology the characteristics selected reflect the type of information an ecologist would require for the ecological evaluation of a proposed action Practical applicability characteristics were developed from a review of the literature on Federal experience with NEPA and with the evaluation of water resource projects prior to NEPA This research identified four issue that were translated into characterisitics (a) to what degree are methodologies ambiguous and subject to individual inter-

pretation? (b) to what degree are evaluations produced by methodologies which are replicable? (c) what kinds of data are required? and (d) what resources, in terms of manpower, time, and money, are required to collect the data? *Political utility* characteristics were identified through the development of a model of the decision-making process applicable to "new start" Bureau of Reclamation water resource projects. This model was utilized to answer two questions pertinent to identification of political utility characteristics (a) what are the characteristics of information processed by the system now? and (b) what characteristics would new environmental information need to possess to be utilized by the system?

3. Commoner (16) has suggested four basic laws of ecology that can be used to devise criteria for impact assessment methodology (parenthetical expressions added)

    (a) Everything is related to everything else. (The earth is a system)

    (b) Everything must go somewhere. (The earth is essentially a closed system, there is no "away" where wastes can be thrown)

    (c) Nature knows best. (Human tinkering with the system should be assumed detrimental until proven otherwise).

    (d) There is no such thing as a free lunch. (Every action has an impact)

4   Three basic methods of impact assessment were compared in these studies, they are

    (a) Battelle Environmental Evaluation System (13)

-11-

(b) Leopold Interaction Matrix (10)

(c) Bureau of Reclamation-Water Resources Council Method (...

B. Ecological Criteria for Impact Methodologies

'. Holism

(a) Does the methodology recognize the interactive charactı ı
of natural and man-dominated systems?

(b) Does it require description of the impacted environment
as an ecosystem or series of ecosystems?

2 Separation of effects

(a) Does the methodology separate future project-induced
effects from expected non project-induced changes?

(b) Does it require explicit statement of assumptions made
in projecting the without-project future environment
from present conditions?

3. Timing and duration

Does the methodology identify the timing and duration ı
expected impacts?

4 Scale of significance

(a) Does the methodology identify the geographic extent nin
location of impacts?

(b) Does it interpret changes in wildlife populations ı ι
terms of tne viability and distribution of the remaini· g
population--locally, regionally, and nationally?

5 Resource stocks

Does the methodology as ıcss the utilization of non-
renewable resources in terms ot remaining stocks'

6. Indirect effects

> Does the methodology identify indirect effects such as additional environmental stresses caused by stimulated regional growth? The dividing line between direct and indirect environmental impacts is frequently vague In this research direct impacts are defined as direct or first-order effects of project activities. Indirect impacts are second or higher-order effects triggered by direct impacts.

7. System functions

> Does the methodology express impacts in terms of the following functional characteristics

(a) Cycling of nutrients and/or energy

(b) Gross and net system biological productivity

(c) System diversity--both spatial and biological

(d) System stability or resiliency

(e) System evolution--continuing rates and direction of change?

8. Quantification

(a) Does the methodology express impacts in objectively measurable units?

(b) Does it express impacts in commensurable units?

(c) Are the bases for valuations and weightings used to obtain the commensurability explicitly stated?

9. Uncertainty

> Does the methodology require an assessment of the analyst's degree of confidence in his impact projections?

-13-

10   Risk

        Does the methodology require identification and assessm

        of impacts with low probability but high possible losse

11. Monitoring

        Does the methodology require consideration of the adequ

        of existing or proposed monitoring of critical or highl

        uncertain aspects of the proposed action's effects on th

        system?

C. Application of Ecological Criteria

    1. In using these criteria to analyze the methodologies under stu

        three questions were asked concerning each criterion. a. Doe

        the methodology incorporate the concept involved? b. Does it

        suggest a technique for dealing with the concept? c How

        adequate is the suggested approach?

    2 Conclusions from the analysis of the three methodologies are

        summarized in Tables 2 through 4.

D. Practical Applicability Criteria for Impact Methodologies

    1 These criteria basically deal with how the impact informat

        is to be generated.

    2. The specific criteria are ambiguity, replicability, data

        availability and resource requirements (manpower, time, mo

        and technology)

    3 Conclusions from the analysis of the three methodologies are

        summarized in Table 5.

E. Political Utility Criteria for Impact Methodologies

    1. The basic information generated must be evaluated in term

        of its ability to effect a change in the process actors o

TABLE 2

Summary analysis of the Battelle approach

	Concept Recognized?	Technique or Use Proposed?	Adequacy of Treatment
1. *Holism*			
a. Interaction	yes	yes	adequate
b. Ecosy. tem descriptions	yes	yes	adequate
2. *Separation of effects*			
a. Project-non project	yes	yes	adequate
b. Without project assumptions	yes	no	inadequate
3. *Timing and duration*	yes	yes	adequate
4. *Scale of significance*			
a. Geographic extent	yes	yes	adequate
b. Population viability	yes	yes	partially adequate
5. *Resource stocks*	no	no	inadequate
6. *Indirect effects*	yes	yes	inadequate
7. *Systems functions*			
a. Cycling	yes	yes	inadequate
b. Diversity	yes	yes	inadequate
c. Productivity	yes	yes	several scattered uses
d. Stability-resiliency	no	no	inadequate
e. Evolution	no	no	inadequate
8. *Quantification*			
a. Measurability	yes	yes	adequate
b. Commensurability	yes	yes	adequate
c. Weighting	yes	yes	generally explicit
9. *Uncertainty*	no	no	inadequate
10. *Risk*	no	no	inadequate
11. *Monitoring*	no	no	inadequate

TABLE 3

Summary analysis of the Leopold approach

	Concept Recognized?	Technique or Use Proposed?	Adequacy of Treatment
1. Holism			inadequate
a. Interaction	yes	yes	variable with
b. Ecosystem descriptions	yes	yes	analyst
2. Separation of effects			
a. Project-non project	no	no	inadequate
b. Without project assumptions	no	no	inadequate
3. Timing and duration	yes	partial	inadequate
4. Scale of significance			inadequate
a. Geographic extent	yes	partial	variable with
b. Population viability	yes	partial	analyst
5. Resource stocks	yes	no	variable with analyst
6. Indirect effects	yes	no	inadequate
7. System functions			inadequate
a. Cycling	yes	yes	indirect
b. Diversity	no	no	references
c. Productivity	no	no	inadequate
d. Stability-resiliency	no	no	inadequate
e. Evolution	no	no	inadequate
8. Quantification			
a. Measurability	yes	yes	subjective
b. Commensurability	yes	yes	potentially misleading
c. Weighting	no	no	not applicable
9. Uncertainty	partial	partial	inadequate
10. Risk	partial	partial	inadequate
11. Monitoring	no	no	inadequate

TABLE 4

Summary analysis of the WRC approach

	Concept Recognized?	Technique or Use Proposed?	Adequacy of Treatment
1. Holism			
a. Interaction	no	no	inadequate
b. Ecosystem descriptions	no	no	inadequate
2. Separation of effects			
a. Project-non project	yes	yes	adequate
b. Without project assumptions	no	no	inadequate
3. Timing and duration	yes	no	artificial period of analysis
4. Scale of significance			
a Geographical extent	yes	no	inadequate
b. Population viability	yes	no	inadequate
5. Resource stocks	no	no	inadequate
6. Indirect effect	no	no	inadequate
7. System functions			
a. Cycling	no	no	inadequate
b. Diversity	yes	no	inadequate
c. Productivity	no	no	inadequate
d Stability-resiliency	no	no	inadequate
e. Evolution	yes	no	inadequate
8. Quantification			
a Measurability	yes	yes	both quantitative and qualitative
b. Commensurability	no	no	not attempted
c. Weighting	yes	yes	recognize "neutral" inputs
9. Uncertainty	yes	yes	adequate
10. Risk	yes	partially	partially adequate
11. Monitoring	no	no	inadequate

TABLE 5

Summary of practical applicability analysis

Characteristic	WRC	Leopold	Battelle
Ambiguity	high	high	low
Replicability	very low	low	high
Data Availability	high	high	low
Resource Requirements			
Manpower	moderate-nonspecific	low-nonspecific	moderate-specific
Time	variable	low	moderate-high
Money	variable	low	moderate-high
Technology	variable	variable	specific

their behavior.

2. The specific criteria and a summary of the evaluation of the three methodologies in relation to them are shown in Table 6.

F. Methodologies for Impact Analysis

1. Warner in 1973 and Warner and Bromley in 1974 divided impact methodologies into 5 main classes.

(a) Ad hoc procedures

(b) Overlay techniques

(c) Checklists

(d) Matrices

(e) Networks

2. Ad hoc procedures, the crudest and oldest, involve little more than assembling a team of specialists to identify impacts in their areas of expertise with minimal guidance beyond the points of NEPA Section 102. This class of approaches represents the approximate starting point of all Federal agencies when NEPA became law.

3. Overlay approaches are well developed techniques of planning and landscape architecture. They use a series of overlaid maps of environmental concerns or land features to discriminate between design alternatives. The overlay approach is generally effective in selecting alternatives and identifying certain types of impacts, but is unable to quantify impacts or identify interaction effects.

4. Checklist approaches attempt to list the types of impacts typically associated with a particular type of project from

-19-

Table 6

Summary of Political Utility Characteristics Evaluation

Characteristics of "Useful" Information	Leopold Approach	WRC Approach	Battelle Approach
Forming winning coalitions			
Identifies points of mutual concern	x		
Facilitates communication	x		x
Identifies compromise positions			x
Changing who participates			
Identifies impacted parties	partially	*	
Communicates to those impacted			
Possesses timeliness			x
Redefining the salience of an issue			
Increases issue visibility	x		partially
Clarifies key features	x	partially	x
Economizes on analytical resources via indicators	partially	partially	x
Redefining self-interest of participants			
Changes perception of impacts	—		x
Changes objectives		*	
Possesses face validity		*	
Modifying the envelope of events and issues			
Redefines issue images		*	~

* The WRC approach as a whole may possess these characteristics though the environmental sections do not.

4   Criteria for Impact Interpretation

(a)   Significance

Does the method require an assessment of significance

on a local, regional and national scale?

(b)   Explicit criteria

Does the method require that the criteria and assumptions

in significance determination be stated?

(c)   Uncertainty

Does the method address uncertainty or the degree of

confidence in impact projections?

(d)   Risk

Does method focus on impacts of low probability of

occurrence but high potential damage?

(e)   Alternatives comparison

Does the method provide a way of comparing alternatives?

(f)   Aggregation

Does the method provide a way for aggregation of information

on impact measurement and interpretation?

(g)   Public involvement

Does the method provide a way for public input in the

interpretation of impact significance?

5.   Criteria for Impact Communication

(a)   Affected parties

Does the method link impacts to affected human groups?

(b)   Setting description

Does the method require a description of the environmental

setting?

(c) Summary format

Does the method contained a suggested summary format?

(d) Key issues

Does the method suggest a way of highlighting key

impacts or issues?

(e) NEPA Compliance

Does the method focus on NEPA/CEQ requirements?

6 Resource Requirements

(a) Data requirements

Does the method use current data or are special studies

required?

(b) Manpower requirements

Special skills?

(c) Time requirements

How much time is necessary to "learn" the method?

(d) Costs

What are the costs of using the method?

(e) Technologies

Are special technologies required?

7. Replicability

(a) Ambiguity

Is the method ambiguous?

(b) Analyst bias

To what degree will different results occur depending on

the analyst?

2   Be Flexible

Sufficient flexibility must be contained in the methodology,
as projects of different size and scale result in different
types of impacts.

3.   Detect True Impact

The actual impact is always that change in environmental
conditions resulting from a project, as opposed to the
change that would naturally occur - not merely to existing
conditions. Moreover, both short-term and long-term changes
must be measured.

4   Be Objective

The methodology must be objective, providing impersonal,
unbiased, and constant yardsticks immune to outside tampering
by political and other external forces. An objective and
consistent procedure provides a firm foundation upon which
periodic updating, refinement, and modification can be accom-
plished, thereby incorporating the experience gained through
practical application. To be effective as a decision-making
tool, environmental impact assessments also must be replicable
by different analysts and able to withstand scrutiny by various
interest groups.

5.   Insure Input of Required Expertise

Sound, experienced, professional judgement must be assured by
a methodology, especially as subjectivity remains inherent in
many aspects of environmental evaluation   Input of the
necessary expertise can be achieved either through the design

-27-

of the methodology itself or through the rules governing
its use.

6   Utilize the State of the Art

Maximum appropriate use of the state of the art must be made,
drwing on the best available analytical techniques.

7. Employ Explicityly Defined Criteria

Evaluation criteria, especially any quantified values, employed
to assess the magnitude or importance of environmental impacts
should not be arbitrarily assigned. The methodology must provide
explicitly defined criteria and explicitly stated procedures
regarding the use of these criteria, with the rationale behind
such criteria documented.

8. Assess Actual Magnitude of Impacts

Means must be provided for an assessment based on specific levels
of impact for each environmental concern, in the specific terms
established for describing that concern (e.g , BOD, pH, tempera-
ture, etc., for water quality). Assessment of magnitude based
on generalities or relatives (qualitative comparisons between
alternatives) is inadequate.

9. Provide for Overall Assessment of Total Impact

A means for aggregating multiple individual impacts is necessary
to provide an evaluation of overall total environmental impact

10. Pinpoint Critical Impacts

The methodology must provide a warning system to pinpoint and
emphasize particularly hazardous impacts. In some cases the
sheer intensity or magnitude of impact may justify special

.

attention in the planning process, regardless of how narrowly
the impact might be felt.

B. Description of Study

1. 23 environmental impact assessment methodologies were
   evaluated based on the above 10 criteria. A short description
   of each method in the study not previously described in Appen-
   dix A is included in Appendix B.

2. The 23 methodologies were divided into the following groups

   (a) Ad Hoc Committee Approach

       1. Eckenrode   (App. B)

       2. Lamanna   (App. B)

       3. McKenny   (App. B)

   (b) Overlays

       4. McHarg   (App. A)

       5. Lacate   (App B)

       6. Baker and Greundler   (App. B)

       7 Turner and Hausmanis (App. B)

   (c) Checklists – Type A(list of parameters without any systematic
       procedured guidelines for using parameter data, and without
       any explicitly-stated criteria for determing the magnitude
       of a given impact).

       8. Leopold (App. A)

       9. Manheim (App. B)

       10. Sorensen (App. A)

   (d) Checklists – Type B (checklist methodology including ·
       systematic framework for the use of collected data ·n

-29-

evaluation, does not offer criteria for determing impact
magnitude or for measuring the relative importance of a
particular parameter).

11.	Little	(App. A)
12.	Adkins and Burke	(App. A)
13.	Washington State	(App. B)
14.	Hill	(App. B)
15.	Klein	(App. B)
16.	Oglesby, et al	(App. B)
17.	SE Wisconsin	(App. B)
18.	Stover	(App. B)

(e) Checklists - Type C (Type B plus explicitly-stated criteri
for determining what constitues an impact of a given
magnitude and what its relative importance is. This
final type has the advantage of not only providing a
list for identifying impacts, but also a framework for
measuring the magnitude of individual impacts, and a
means for assessing overall project impact by aggregating
individual impacts in proportion to their relative
importance).

19	Dearinger	(App. B)
20.	Dec-1972	(App A)
21.	Georgia	(App. A)
22.	Orlob, et al	(App. B)
23.	Walton and Lewis	(App. A)

3. Table 8 summarizes the extent to which each method meets the ten criteria listed before as basic requirements for an adequate assessment procedure

VII. Summary of Impact Methodologies

    A. Current Status (April, 1975)

        1. Reported methods are shown in Table 9

        2. 33 methods are described in either Apendix A or B, 14 additional methods described in the CPL Bibliography (9)

        3 It is safe to say that over 50 methods have probably been utilized as environmental impact assessment techniques since many are not reported as separate methods.

    B. Some Future Needs (6)

        1. Future methodological improvements should concentrate on the interpretation and communication of impacts.

        2. Methodologies should provide for the assessment of impact analysis reliability.

        3. A system for allocating environmental assessment resources should be developed by CLQ.

        4 The public should play an active rather than a passive role in the evaluation of impact significance

        5 The current environmental impact statement preparation system should be considered an interim measure to be replaced by a more streamlined procedure closely tied to integrated land use planning

TABLE 8

Methodology Summary Chart

Methodology Number	Degree to Which Indicated Requirement is Fulfilled*									
	1	2	3	4	5	6	7	8	9	10
1	S	S	S	N	N	N	N	N	N	N
2	S	S	S	N	N	N	N	N	N	N
3	L	L	L	S	S	N	N	L	L	S
	L	L	N	L	L	L	L	N	N	S
5	S	S	N	N	S	N	S	N	N	S
6	L	L	N	L	L	L	L	N	N	S
7	L	L	N	L	L	L	L	N	N	S
8	S	S	S	N	N	S	N	S	N	N
9	N	L	S	N	N	S	S	S	S	S
10	S	L	L	S	N	N	N	N	N	S
11	S	S	N	N	N	N	N	N	N	N
12	S	S	S	N	N	S	N	S	L	N
13	S	S	S	N	N	S	S	S	L	S
14	S	L	N	N	N	S	S	N	S	N
15	S	S	S	L	S	L	L	L	S	N
16	S	S	N	N	N	S	S	N	N	N
17	S	S	N	N	N	S	N	N	N	N
18	L	S	L	S	S	S	S	S	L	N
19	S	S	S	L	S	L	L	L	S	N
20	L	S	L	L	L	L	L	L	L	L
21	L	S	L	S	S	L	S	L	L	N
22	S	S	N	L	S	L	L	N	N	N
23	N	N	S	L	S	N	N	S	N	N

*N: Little or no fulfillment.
S: Requirement fulfilled to some extent.
L: Requirement fulfilled to a large extent.

TABLE 9   Summary of Environmental Impact Assessment Methodologies

Environmental Assessment Method	Dickert in 1972	Warner in 1973	Warner and Preston in 1973	Smith in 1974	Method Description (Appendix)	CPI Bibliography
Leopold	X(M)	X(NS)	X(M)	X(C-A)	A	X
Sorensen	X(M)		X(N)	X(C-A)	A	
Odum	X(M)					
Dee-Battelle (1972)	X(NS)	X(NS)	X(C)	X(C-C)	A	X
Georgia	X(NS)		X(C)	X(C-C)	A	X
Seattle	X(NS)					
WRC Task Force		X(NS)	X(C)		A	
Adkins			X(C)	X(C-B)	A	
Dee-Bettelle (1973)			X(C-M)		A	
Krauskopf			X(O)		A	λ
Little			X(C)	X(C-B)	A	
McHarg			X(O)	X(O)	A	
Moore			X(M)		A	
New York			λ(M)		A	X
Smith			X(C)		A	
Stover			X(C)	X(C-B)	A	\
Tulsa			X(C)		A	\
Walton			X(C)	X(C-C)	A	
WSCC			X(AH)		A	\
Eakenrode				X(AH)	B	
Lamanna				X(AH)	B	
McKenny				X(AH)	B	
Lacate				X(O)	B	
Baker & Greundler				X(O)	B	
Turner and hausmanis				X(O)	B	
Mannheim				X(C-A)	B	
Washington State				X(C-B)	B	

Hill				X(C-B)	B		
Klein				X(C-B)	B		
Oglesby				X(C-B)	B		
SE Wisconsin				λ(C-B)	B		
Dearinger				X(C-C)	B		
Orlob				X(C-C)	B		
Fischer and Davies							λ
Pikul							X
BLM							ℵ
Commonwealth							λ
Alden							X
CERL							ℵ
BOR-Wisconsin							ℵ
Research Planning							λ
Ellis and Lewis							λ
E I Center							λ
Kane							
Gibon ?							ℵ
Hutting							ℵ
Harvard							λ

M   = matrix
NS = not specified
N   = network
C   = checklist
C-M = checklist matrix

O   = overlay
AH = ad hox
C-A = checklist – Type A
C-B = checklist – Type B
C-C = checklist – Type C

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APPENDIX A

SOME METHODS OF

ENVIRONMENTAL IMPACT ANALYSIS

(After Warner and Preston, "A Review of
Environmental Impact Assessment Methodologies",
Contract No. 68-01-1971, U.S. Environmental
Protection Agency, 1973.)

1. Adkins, William G. and Dock Burke Jr., Interim Report·
   Social, Economic, and Environmental Factors in Highway
   Decision Making, research conducted for the Texas
   Highway Department in cooperation with the U.S.
   Department of Transportation, Federal Highway Admin-
   istration: College Station, Texas; Texas Transportation
   Institute, Texas A&M University (October 1971).

The Adkins methodology is a checklist using a +5 to -5 rating system
for evaluating impacts but providing no guidelines for measuring impacts.
The approach was developed to deal specifically with the evaluation of
highway route alternatives. Because the bulk of parameters used relate
directly to highway transportation, the approach is not readily adaptable
to other types of projects.

The parameters used are broken down into categories of transportation,
environmental, sociological, and economic impact. Environmental parameters
are generally deficient in ecological considerations. Social parameters
emphasize community facilities and services.

Route alternatives are scored +5 to -5 in comparison to the present
state of the project area, not the expected future state without the project.
Since the approach uses only subjective relative estimations of impacts, the
data, manpower, and cost requirements are very flexible. Reliance on sub-
jective ratings without guidelines for such ratings greatly reduces the
replicability of analysis and generally limits the valid use of the approach
to a case-by-case comparison of alternatives only.

The detailed listing of social and, to a lesser extent, economic parameters may be helpful for identifying and cataloging impacts in other types of projects. An interesting feature of possible value to other analyses using relative rating systems is the practice of summarizing the number as well as the magnitude of plus and minus ratings for each impact category. The number of pluses and minuses may be a more reliable indicator for alternative comparison since it is less subject to the arbitrariness of subjective weighting. These summarizations are additive and thus implicitly weigh all impacts equally.

2. Dee, Norbert, et al, <u>Environmental Evaluation System For Water Resources Planning</u>, report to the U.S. Bureau of Reclamation, Columbus, Ohio: Battelle Memorial Institute (January 1972).

This methodology is a checklist procedure emphasizing quantitative impact assessment. It was designed for major water resource projects but most parameters used are also appropriate for other types of projects. Seventy-eight specific environmental parameters are defined within the four categories of ecology, environmental pollution, aesthetics, and human interest. The approach does not deal with economic or secondary impacts and social impacts are only partially covered within the human interest category.

Impacts are measured via specific indicators and formulas defined for each parameter. Parameter measurements are converted to a common base of "environmental quality units" through specifics graphs or value functions. Impacts can be aggregated using a set of preassigned weights.

The resource requirements are rather high, particularly data requirements. These requirements probably restrict the use of the approach to major project assessments.

The approach emphasizes explicit procedures for impact measurement and evaluation and should therefore produce highly replicable results. Both spatial and temporal aspects of impacts are noted and explicitly weighted in the assessment. Public participation, uncertainty, and risk concepts are not dealt with. An important idea of the approach is the highlighting of key impacts via a "red flag" system.

3. Dee, Norbert, et al., Planning Methodology for Water Quality Management: Environmental Evaluation System, Columbus, Ohio: Battelle Memorial Institute (July 1973).

This unique methodology of impact assessment defies ready classification since it contains elements of checklist, matrix, and network approaches. Areas of possible impacts are defined by a hierarchical system of four categories (ecology, physical/chemical, aesthetic, social), 19 components and 64 parameters. An interaction matrix is presented to indicate which activities associated with water quality treatment projects generally impact which parameters. The range of parameters used is comprehensive, excluding only economic variables.

Impact measurement incorporates two important elements. A set of "ranges" is specified for each parameter to express impact magnitude on a scale from zero to one. The ranges assigned to each parameter within a component are then combined by means of an "environmental assessment tree" into a summary environmental impact score for that component. The significance of impacts on each component is quantified by a set of assigned weights. A net impact can be obtained for any alternative by multiplying each component score by its weight factor and summing across components.

The key features of the methodology are its comprehensiveness, its explicitness in defining procedures for impact identification and scoring, and its flexibility in allowing use of best available data.

Sections of the report explain the several uses of the methodology in an overall planning effort and discuss means of public participation. The data, time, and cost requirements of the methodology when used for impact assessment are moderate, though a small amount of training would be required to familiarize users with the techniques used.

Because of its explicitness, the methodology possesses only minor ambiguities and should be highly replicable. Because the environmental assessment trees are developed specifically for water treatment facilities, the methodology cannot be adapted to other types of projects without reconstructing the trees though the parameters could be useful as a simple checklist.

141

One potentially significant obstacle to use of the approach is the difficulty of explaining the procedures to the public. Regardless of the validity of the "trees", they are unfamiliar devices developed by highly specialized multivariant analysis techniques and public acceptance of conclusions reached by their use may be low.

4. Institute of Ecology, University of Georgia, "Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process: Test case: Relative Impact of Proposed Highway Alternatives", Athens, Georgia: University of Georgia, Institute of Ecology (1971) (mimeographed).

The "Georgia" methodology incorporates a checklist of 56 environmental components. Measurable indicators are specified for each component. The actual values of alternative plan impacts on a component are normalized and expressed as a decimal of the largest impact (on that one component). These normalized values are multiplied by a subjectively determined weighting factor. This factor is the sum of one times a weight for "initial" effects plus ten times a weight for "long-term" effects.

The methodology is used to evaluate highway project alternatives and the components listed are not suitable for other types of projects. A wide range of impact types are analyzed including land use, social, aesthetics, and economic impacts.

The lower replicability of the analysis produced by using subjectively determined weighting factors is compensated for by conducting several passes at the analysis, and incorporating randomly generated error variation in both actual measurements and weights. This procedure provides a basis for testing the significance of differences in total impact scores between alternatives.

The procedures for normalizing or scaling measured impacts to obtain commensurability, and testing of significant differences between alternatives are notable features of potential value to other impact analyses and methodologies. These ideas may be useful whenever several project alternatives can be identified and compared

The Georgia methodology places rather high resource demands on the user since computerization is necessary to generate random errors and make the large number of repetitive calculations.

4

5. Krauskopf, Thomas M., and Dennis C. Bunde, "Evaluation of Environmental Impact Through a Computer Modelling Process", Environmental Impact Analysis: Philosophy and Methods, (eds.) Robert Ditton and Thomas Goodale, Madison, Wisconsin: University of Wisconsin Sea Grant Program (1972), pp. 107-125.

This methodology employs an overlay technique via computer mapping. Data on a large number of environmental characteristics are collected and stored in the computer on a grid system of 1 km square cells. Highway route alternatives can either be evaluated by the computer (by noting the impacts on intersected cells) or new alternatives may be generated via a program identifying the route of least impact.

The environmental characteristics used are rather comprehensive, particularly as regards land use and physiographic characteristics. Though the methodology was developed and applied to a highway setting, it is adaptable, with relatively small changes in characteristics examined, to other project types with geographically well defined and concentrated impacts. Because the approach requires considerable amounts of data on the project region, it is not practical for the analysis of programs of broad geographical scope. The high manpower-skill, money, and computer technology requirements of the approach may also make it impractical at the present time for any but major projects, or in situations where a statewide, computerized data base exists (New York, Minnesota, Iowa, etc).

The estimation of impact importance is done through the specification of subjective weights. Because the approach is computerized, the effects of several alternative weighting schemes can be readily analyzed.

The methodology is attractive on several viewpoints. It allows a demonstration of which weighted characteristics are central to a particular alternative route; it presents a readily understandable graphic representation of impacts and alternatives, it easily handles several subjective weighting systems; the incremental costs of considering or generating additional alternatives is low; and it fits well with developing regional and statewide data bank systems.

The mechanics of the approach--how impacts are measured and combined--are not readily apparent from the reference cited. Considerable training beyond the information available in this reference would be required to use the approach.

> 6. Leopold, Luna B., et al., A Procedure for Evaluating Environmental Impact, Geological Survey Circular 645, Washington: Government Printing Office (1971).

This is an open-cell matrix approach identifying 100 project activities and 88 environmental characteristics or conditions. For each action involved in a project, the analyst evaluates the impact on every impacted environmental characteristic in terms of impact magnitude and significance. These evaluations are subjectively determined by the analyst. Ecological and physical-chemical impacts are treated comprehensively, social and indirect impacts are less well handled, and economic and secondary impacts are not addressed.

Because the assessments made are subjective, resource requirements of the approach are very flexible. The approach was not developed in reference to any specific type of project and may be broadly applied with some alterations.

Guidelines for use of the approach are minimal and several important ambiguities are likely in the definition and separation of impacts. The reliance on subjective judgment, again without guidelines, reduces the replicability of the approach.

The approach is chiefly valuable as a means of identifying project impacts and as a display format for communicating results of an analysis.

> 7. Arthur D. Little, Inc., Transportation and Environment Synthesis for Action   Impact of National Environmental Policy Act of 1969 on the Department of Transportation, Vol. 3, Options for Environmental Management, prepared for Office of the Secretary, Department of Transportation (July 1971).

This is less a complete methodology than an overview discussion of the kinds of impacts that may be expected to occur from highway projects and the measurement techniques that may be available to handle some of them. A quite comprehensive list of impact types and the stages of project development at which each may occur are presented. As broad categories, the impact types identified are useful for other projects as well as for highways.

The approach suggests the separate consideration of an impact's amount, effect (public response), and value. Some suggestions are offered for measuring the amount of impact within each of seven general categories. noise, air quality, water quality, soil erosion, ecologic, economic, and sociopolitical impacts.

Five possible approaches to the handling of impact significance are presented. Three of these are "passive" (requiring no agency action) such as "reliance on the emergence of controversy". The other two involve the use of crude subjective weighting scales. No specific suggestions are made for the aggregation of impacts either within or between categories.

In general, the reference cited is a useful discussion of some of the important issues of impact analysis, particularly as they apply to transportation projects, but does not present a complete analytical technique.

8. McHarg, Ian., "A Comprehensive Highway Route-
    Selection Method", Highway Research Record,
    Number 246, 1968, pp. 1-15, or McHarg, Design
    With Nature, Garden City, New York: Natural
    History Press, 1969, pp. 31-41.

The McHarg approach is a system employing transparencies of environmental characteristics overlaid on a regional base map. Eleven to sixteen environmental and land use characteristics are mapped. The maps represent three levels of the characteristics, based upon "compatibility with the highway". These references do not indicate how this compatibility is to be determined but available documentation is cited.

This approach is basically an earlier, noncomputerized version of the ideas presented in the Krauskopf reference. Its basic value is as a method for screening alternative project sites or routes. Within this limited use, it is applicable to a variety of project types.

Limitations of the approach include its inability to quantify as well as identify possible impacts and its implicit weighting of all characteristics mapped.

Resource requirements of the McHarg approach are somewhat less demanding, in terms of data, than those of the Krauskopf approach because information is not directly quantified, only categorized into three levels. High degrees of skill and training are required, however, to prepare the map overlays.

143

The approach seems most useful as a "first cut method" of identifying and sifting out alternative project sites, preliminary to detailed impact analysis.

9. Moore, John L., et al., A Methodology for Evaluating Manufacturing Environmental Impact Statements for Delaware's Coastal Zone, Report to the State of Delaware, Columbus, Ohio: Battelle Memorial Institute (June 1973).

This approach was not designed as a method for impact analysis but its principles could be adapted for such use. It employs a network approach linking a list of manufacturing-related activities-to potential environmental alterations-to major environmental effects, and finally-to human uses affected. The primary strength of the set of linked matrices is their utility in displaying cause-condition-effect networks and tracing out secondary impact chains.

Such networks are useful primarily for identifying impacts and the issues of impact magnitude and significance are addressed only in terms of high, moderate, low, or negligible damage. As a result of these subjective evaluations the approach would have low replicability as an assessment technique. For such a use, guidelines would likely need to be proposed to define the evaluation categories.

The approach incorporates indicators especially tailored to manufacturing facilities in a coastal zone though most indicators would also be pertinent to other types of projects.

The approach would perhaps be valuable as a visual summary of an impact analysis for communication to the public and decision makers.

10. Central New York Regional Planning and Development Board, Environmental Resources Management, prepared for Department of HUD (October 1972) (available through the National Technical Information Service PB 217-517).

This methodology employs a matrix approach to assess in simple terms the major and minor, direct and indirect impacts of certain water related construction activities. It is designed primarily to measure only the physical impacts of water resource projects in a watershed, and is based on an identification of the specific, small-scale component activities that are included in any project. Restricted to physical impacts on nine

8

different types of watershed areas (e.g., wetlands) and fourteen types
of activities (e.g., tree removal), the procedure indicates four possible
levels of impact-receptor interactions (major direct through minor indirect).
Low to moderate resources in terms of time, money, or personnel are required
for the methodology, due principally to its simple way of quantification
(major versus minor impact). However, the procedure is severely limited in
its ability to compare different projects or the magnitude of different
impacts. There is no spatial or temporal differentiation, hence the full
range of impacts cannot be assessed. Impact uncertainty and high damage-
low probability impacts are also not considered. Only two levels of the
magnitude of an impact are identified while the importance of the impacts
are not assessed, resulting in moderate replicability. The lack of objec-
tive evaluation criteria may produce ambiguous results. NEPA requirements
for impact assessments are not directly met by this procedure.

The value of this methodology is less in the actual assessment
of the quantitative impacts of a potential project than in a "capability
rating system" which determines recommended development policies based on
existing land characteristics. Thus, guidelines on desirable and undesirable
activities with respect to the nine types of watershed areas are used to
map a region in terms of the optimum land use plan. The actual mapping
procedure is not described, however, and hence that aspect of the impact
assessment methodology cannot be evaluated here.

> 11. Smith, William L., "Quantifying the Environmental
>   Impact of Transportation Systems", Van Doren-
>   Hazard-Stallings-Schnacke, Topeka, Kansas (undated)
>   (mimeographed).

The Smith approach, as developed for highway route selection,
is a checklist system based on the concepts of probability and supply-
demand. The approach attempts to identify the alternative with least
social cost to environmental resources and maximum social benefit to
system resources. Environmental resources elements are listed as·
agriculture, wildlife conservation, interference, noise, physical features,
and replacement. System resources elements are listed as. aesthetics,
cost, mode interface, and travel desires. For each element, categories
are defined and used to classify zones of the project area. Numerical
probabilities of supply and of demand are then assigned to each zone for
each element. These are multiplied to produce a "probability of least

social cost" (or maximum social benefit). These least social cost probab'' ties are then multiplied across the elements to produce a total fo the route alternative under examination.

The approach is tailored and perhaps limited to project situations requiring comparison of siting alternatives. The range of environmental factors examined is very limited, but presumably could be expanded to cover more adequately ecological, pollution, and social considerations.

Since procedures for determining supply and demand probabilities are not described, it is difficult to anticipate the amounts of data, manpower and money required to use the approach. The primary limitations of this methodology are difficulties inherent in assigning probabilities, particularly demand probabilities, and the implicitly equal weightings assigned to each element analyzed when multiplying to yield an aggregate score for an alternative.

12. Sorensen, Jens, A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, Berkeley· University of California, Department of Landscape Agriculture (1971), and Sorensen and James E. Pepper, Procedures for Regional Clearinghouse Review of Environmental Impact Statements -- Phase Two, report to the Association of Bay Area Governments (April 1973).

These two publications present a network approach usable for environmental impact analysis. The approach is not a full methodology but rather a guide to the identification of impacts. Several potential uses of the California coastal zone are examined through networks relating uses-to causal factors (project activities)-to first order condition changes-to second and third order condition changes, and finally-to effects. The major strength of the approach is its ability to identify the pathways by which both primary and secondary environmental impacts are produced.

The second reference also indicates types of data relevant to each effect identified, though no specific measurable indicators are suggested. In this reference some general criteria for identifying projects of regional significance are suggested, based on project size and types of impacts generated, particularly land use impacts.

10

Because the preparation of the required detailed networks is
a major undertaking, the approach is presently limited to some commercial,
residential, and transportation uses of the California coastal zone for
which networks have been prepared. An agency wishing to use the approach
in other circumstances might develop the appropriate networks for reference
in subsequent environmental impact assessments.

13. Stover, Lloyd V., Environmental Impact Assessment:
A Procedure, Miami, Florida: Sanders and Thomas,
Inc. (1972).

This methodology is a checklist procedure for a general
quantitative evaluation of environmental impacts from development activities.
The type and range of these activities is not specified, but is believed
to be comprehensive. Fifty different impact parameters are sufficient to
include most possible effects, and thereby allow much flexibility. Sub-
parameters indicate specific impacts, but there is no indication of how
the individual measures are aggregated into a single parameter value. While
spatial differences in impacts are not indicated, both initial and future
impacts are included and explicitly compared. Resource requirements are
moderate to heavy, especially in terms of an interdisciplinary personnel
team which grows as more subparameters are included, requiring additional
expertise in specific areas. However, the actual measurements are not
based on specific criteria and are only partially quantitative, with seven
possible values ranging from an extremely beneficial impact to an extremely
detrimental one. Therefore, there is potential for ambiguous and subjective
results, with only moderate replicability. Impact areas are implicitly
assumed to be of equal importance. A specific methodology is mentioned
for choosing the optimum alternative in terms of benefits and adverse
effects. The procedure for alternatives comparison may be the most
interesting aspect of the procedure, with results given in terms of the
proportional significance of an impact vis-a-vis other potential alterna-
tives. There is no explicit mention of either public involvement in the
process, or environmental risks.

The impact assessment procedure is presented as only one step
in a total evaluation scheme which includes concepts of dynamic ecological
stability and other ideas. An actual description of the entire process
is not included, however.

11

14. Multiagency Task Force, "Guidelines for Implementing Principles and Standards for Multiobjective Planning\ of Water Resources", Review Draft, Washington: U.S. Bureau of Reclamation (1972).

The Task Force approach is an attempt to coordinate features of the water Resources Council's Proposed Principles and Standards for Planning Water and Related Land Resources with requirements of NEPA. It develops a checklist of environmental components and categories organized in the same manner as the WEC Guidelines. The categories of potential impacts examined deal comprehensively with biological, physical, cultural, and historical resources, and pollution factors but do not treat social or economic impacts. Impacts are measured in quantitative terms where possible and also rated subjectively on "quality" and "human influence". In addition, uniqueness and irreversibility considerations are included where appropriate. Several suggestions for summary tables and bar graphs are offered as communications aids.

The approach is general enough to have wide applicability to various types of projects, though its impact categories are perhaps better tailored to rural than urban environments. No specific data or other resources are required to conduct an analysis, though an interdisciplinary project team is specified to assign the subjective weightings Since quality, human influence, uniqueness, and irreversibilities are all subjectively rated using general considerations only, results produced by the approach may be highly variable. Significant ambiguities include a generally inadequate explanation of how human influence impacts are to be rated and interpreted

Key ideas incorporated in the approach include explicit identification of the without-project environment as distinct from present conditions, and use of uniqueness rating system for evaluating quality and human influence (worst known, average, best known, etc). The methodology is unique among those examined in not labeling impacts as environmental benefits or costs but only as impacts to be valued by others. The approach also argues against the aggregation of impacts.

12

15. Tulsa District, U.S. Army Corps of Engineers,
Matrix Analysis of Alternatives for Water Resource
Development, draft technical paper (July 31, 1972).

Despite the title, this methodology can be considered a checklist under the definitions used here since, though a display matrix is used to summarize and compare the impacts of project alternatives, impacts are not linked to specific project actions. The approach was developed to deal specifically with reservoir construction projects but could be readily adapted to other project types.

Potential impacts are identified within three broad objectives: environmental quality, human life quality, and economics. For each impact type identified, a series of factors are described, indicating possible measurable indicators. Impact magnitude is not measured in physical units but by a relative impact system. This system assigns the future state of an environmental characteristic without the project a score of zero; then assigns the project alternative possessing the greatest impact on that characteristic a score of +5 (for positive impact), or -5 (for negative impact). All other alternatives are assigned scores between 0 and 5 by comparison. The raw scores thus obtained are multiplied by weights determined subjectively by the impact analysis team.

Like the Georgia approach, the Tulsa methodology tests for the significance of differences between alternatives by introducing error factors and conducting repeated runs. The statistical manipulations are different from those used in the Georgia approach, however, and considered by the Corps' writers to be more valid.

Resource requirements of the Tulsa methodology are variable. Since specific types or levels of data are not required, data needs are quite flexible. The consideration of error, however, requires specific skills and computer facilities.

The major limitations of the approach, aside from the required computerization, are the lack of clear guidelines on exactly how to measure impacts and the lack of guidance on how the future no-project state is to be defined and described in the analysis. Without careful description of the assumptions made, replicability of analyses made using the approach may be low since only relative measures are used. Since all

13

14

measurements are relative, it may also be difficult in some cases to deal with items that are not clearly definable as gains or losses.

The key ideas of wider interest incorporated in the Tulsa approach include reliance on relative rather than absolute impact measurement, statistical tests of significance with error introduction, and specific use of the no-project condition, as a base line for impact evaluation.

> 16. Walton, L. Ellis, Jr., and James E. Lewis, A Manual
> for Conducting Environmental Impact Studies, Virginia
> Highway Research Council (January 1971) (available
> through the National Technical Information Service
> PB-210 222).

The Walton methodology is a checklist, unique in its almost total reliance on social impact categories and strong public participation. The approach was developed for the evaluation of highway alternatives and identifies different impact analysis procedures for the conceptual, corridor, and design states of highway planning. All impacts are measured by either their dollar value or a weighted function of the number of persons affected. (The weights used are to be determined subjectively by the study team.) The basis for most measurements is a personal interview with a representative of each facility or service impacted

Resource requirements for such a technique are highly sensitive to project scale. The extensive interviewing required may make the approach impractical for many medium-size or large projects because agencies preparing impact statements seldom have the necessary manpower or the money to contract for such extensive interviewing.

Analyses produced by the approach may have very poor replicability due to the lack of specific data used and the criticality of the decision regarding boundaries of the analysis since many impacts are measured in numbers of people affected There is also no means of systematically taking into account the extent to which these people are affected.

The key ideas of broader interest put forth by the approach are the use of only social impacts without direct consideration of other impacts (pollution, ecology, etc), the heavy dependence on public involvement and specific suggestions on how the public may be involved, and the recognition of the need for different analyses of different stages of project development.   14

17. Western Systems Coordinating Council, Environmental
    Committee, <u>Environmental Guidelines</u> (1971). (Mr.
    Robert Coe, Southern California Electric Company,
    Environmental Committee Chairman.)

The Environmental Guidelines are intended primarily as a planning
tool for siting power generation and transmission facilities However,
they address many of the concerns of environmental impact analysis and
have been used in the preparation of impact statements. Viewed as an
impact assessment methodology, the approach is an ad hoc procedure,
suggesting general areas and types of impacts but not listing specific
parameters to examine.

The approach considers a range of pollution, ecological,
economic (business economics), and social impacts but does not address
secondary impacts such as induced growth, or energy use patterns. The
format of the approach is an outline of considerations important to the
selection of sites for each of several types of facilities -- e.g.,
thermal generating plants, transmission lines, hydroelectric and pumped
storage, and substations. An additional section offers suggestions for
a public information program.

Since the approach does not suggest specific means of measuring
or evaluating impacts no particular types of data or resources are required.
The application of this approach is limited to the siting of electric
power facilities with little carry over to other types of projects.

147

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    on the Department of Transportation</u>, Vol. 3, <u>Options for Environ-
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16

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Appendix B

(Bibliography of Impact Methodologies
from Smith and Not Included in Appendix A)

Ad Hoc Committee Approach

1. Eckenrode, R T. "Weighting Multiple Criteria." Management Science Vol. 12, No. 3. 1965.

   This methodology is not directed toward environmental impact per se, but to the handling of multiple criteria in general. A team of six to twelve experts rate the importance of criteria using several different ranking and rating techniques on a subjective basis The outcomes are compared for agreement or disagreement. This basic approach has been employed in developing weighting scores for various impact methodologies

2 Lamanna, R. A. "Value Consensus Among Urban Residents" Journal of the American Institute of Planners. Vol 30, No 4. 1964.

   Priority areas of concern are identified by means of responses to a sample survey. Persons interviewed are presented with a list of potential concerns and are asked to weight elements according to importance on a 3 to 1 scale, 3 being most important This method does not insure a sound basis for indicated preferences, and would only determine probable areas of lesser or greater impacts, not extent of impact itself

3. McKenny, C E.B , et al. "Interstate-75, Evaluation of Corridors Proposed for South Florida." University of Miami Center for Urban Studies for Florida Department of Transportation. 1971.

   An ad-hoc interdisciplinary panel of experts is convened to consider the qualitative advantages and disadvantages of proposed routes, making

a recommendation based on a consensus judgment. Subunits of the panel

prepare written reports of probable impacts in their area of expertise

These reports are then discussed in a series of deliberative sessions

and agreement on a recommendation is reached.

This method has been widely employed. It is doubtful, however,

whether extensive expertise could be brought to bear on all projects in

a consistent manner, and whether sufficient time would be available for

the painstaking preparation of reports and deliberations on a case by

case basis.

4   Lacate, D. S. "The Role of Resource Inventories and Landscape Ecology

in the Highway Route Selection Process." Department of Conservation,

Cornell University. 1970.

Highway route alternatives are compared and the optimum route se-

lected based on a subjective analysis of "resource inventories." A

resource inventory is simply the process of collecting data on a partic-

ular factor of social, economic, or environmental concern. The informa-

tion produced by the resource inventories is aggregated in a series of

overlay maps, thus, the method is actually the same as the McHarg method

Unlike McHarg, however, specific features and details are not transformed

into three color shades for evaluation at a generalized, macro-scale

level. This technique, therefore, while avoiding the possible misinter-

pretation and unintentional neglect resulting from simplification, lacks

ease and clarity in employment.

Only four overlay maps are prepared in the case study presented

The first displays the various land uses, the second, type and intensity

of farming; the third, soils, and the last, localized historic, cultural,

.nd environmental values. A large series of overlays would easily re-
sult in some features being buried in detail. The advantages, in fact,
of this method over a general collection and analysis of available
information is difficult to determine.

5. Baker, R.W., and Gruendler, J. D. "A Case Study of the Milwaukee-Green
Bay Interstate Corridor Location." Paper presented at Highway Research
Board Summer Meeting. 1972.

This method, developed at the Environmental Awareness Center of the
University of Wisconsin's Department of Landscape Architecture, is a
computer application of McHarg's overlay method. Considered is a broad
range of factors including environmental, engineering, economic, and
social aspects. Ten increments of shading are used to describe the
total range of values varying from dark (more suitable) to light (least
suitable) for each environmental parameter. The parameters are weighted
according to relative importance (the weighting method is not described)

This technique, like McHarg's, does not predict actual impact, but
only areas of greater or lesser impact. It does delineate those locations
for which more detailed studies might be conducted.

6 Turner, A K., and Hausmanis, I. "Computer-Aided Transportation Corridor
Selection in the Guelph-Dundas Area, Ontario, Canada " Paper presented
at Highway Research Board Summer Meeting. 1972.

This is another application of the computer overlay method. The vari-
ous parameters considered are weighted on a scale ranging from 1 to 10

7 Manheim, M. L., et. al. "Community Values in Highway Location and Design
A Procedural Guide". Urban Systems Laboratory, MIT, for Highway Research
Board September, 1971.

Coordination between an interdiciplinary "location study team" and community groups is used in identifying impacts, the interests affected by the impacts, and appropriate spokesmen for those interests. An impact matrix is devised for each affected interest to describe desciptively each alternative and the corresponding impacts. The information contained in the matrix may be qualitative, pictorial, or numeric. It is the responsibility of the location team to use this information in assisting a "politically responsible official" to make a decision on the proper course of action.

Although more documentation and more detail might be required, and a more comprehensive and expert input be attained, this technique resembles the method developed by Leopold in both its application and its shortcomings.

8. Highway Research Section, Engineering Research Division, Washington State University. "A Study of the Social, Economic and Environmental Impact of Highway Transportation Facilities on Urban Communities." For Washington State Department of Highways. 1968.

Three forms are to be completed for each alternative route for evaluation: one based on appearance consideration, one on sociological considerations, and one on economic considerations. Various parameters describing each of these three subject areas are listed on the respective form.

In evaluating a particular route on appearance, for example, a number between 1 and 10 is assigned to each appearance parameter to describe the route's "desirability" for that parameter. The rating is to be done subjectively by the "administrator and his staff." The rating number is

then multiplied by a weighting factor which has been established by administrators and interested citizens prior to the route rating process, the weights are to reflect the objectives the road is intended to serve. This process is repeated for each parameter three times, as the life of the project has been divided into periods of from 0-5 years, 6-25 years, and 26-50 years—the weights and desirability rating may change with time. The combined 50 year weighted ratings for each appearance factor are aggregated to indicate the overall appearance rating. If a route has similar conditions throughout its entire length, it can be rated as one section. If not, the overall rating for a portion is multiplied by the ratio of its length to that of the entire route. (This process, unfortunately, would make the importance of a particular portion dependent upon its length. Also, no criteria are presented to determine when similar conditions are or are not present.)

Finally, the total weighted rating values on the appearance, sociological, and economic forms completed for each route are listed with construction cost and other monetary considerations on a "Route Comparison Form." This method is very subjective, and as is stated, its value "depends on the skill and ability of the user." Quantification in this technique appears to be primarily for the purpose of making the decision process systematic.

9. Hill, M. "A Method for Evaluating Alternative Plans: The Goals-Achievement Matrix Applied to Transportation Plans." Doctoral dissertation, University of Pennsylvania. 1966.

A matrix is prepared. Across one axis are specific environmental goals (decrease in air pollution, etc.); the other axis contains various

land use categories (residential districts, open space, etc.), subdivided into specific area, buildings, and so forth, which are affected. At each specific subdivision-goal intersection, a "+," "-," or "=" is used to indicate for each alternative route whether there is an increase in goal attainment, a decrease in goal attainment, or no change. A comparison between the alternatives themselves is then made at each land category-goal intersection, using the results of the more specific intersections as a basis for judgment. In other words, each alternative is first compared against the attainment of a goal for a group of specific locations, then compared against another alternative for the broader land use category, with the basis of the latter comparison based on how each alternative fares in the first comparison (in terms of the number of plus's, minus's, and equal signs). By examining the matrix horizontally, a comparison can be made between alternative routes in terms of one specific location for all the goals. By examining the matrix vertically, a comparison can be made in terms of one goal and all the land use categories.

Many subjective decisions are required with this method, both in determining goal achievement for an alternative, and in determining the relative importance of each land use category and each goal. Further it is more suited to assessing the degree to which project objectives/goals are met than to assessing environmental consequences of meeting these goals/objectives.

10. Klein, G. E. "Evaluation of New Transportation Systems." Defining Transportation Requirements - Papers and Discussions. American Society of Mechanical Engineers. 1969.

b

This technique was designed to evaluate systems in terms of economic and social factors; the method could possibly be applied to environmental factors. A utility index similar to the "value functions" devised by the Battelle method is employed. Instead of one fuction defining the quality state, two functions representing the upper and lower limits are presented The evaluator is allowed to make a decision somewhere between the two extremes. Specific criteria used in establishing the functions are placed on the horizontal axis, with the point chosen by the evaluator corresponding on the verticle axis to a 0-10 utility scale. Zero on the utility scale represents the best situation, ten the worst, and the utility index for each factor is translated directly into dollar figures. This dubious procedure is intended to put actual dollar signs on intangible values, with the total evaluation based on relative costs and benefits among alternatives.

11. Oglesby, C. H., Biship, G., and Willeke, G. "Socio-Economic and Community Factors in Planning Urban Freeways." Stanford University research project for California Transportation Agency. October, 1969.

For those nonmonetary aspects of a highway project a "profile" of alternatives is prepared and a list of environmental factors developed. The route with the most beneficial (or detrimental) effect for a particular factor is set at 100 percent (or -100 percent) for that particular factor The effects of the alternative routes are then expressed as a percentage of the effects of the best (or worst) for that factor. The results for all factors considered are shown diagramatically on a scale from -100 (worst) to +100 (best). Any alternative routes that are clearly dominated are eliminated. Paired comparisons are made for the remaining

alternatives Subjective decisions are required, as each factor is con-
sidered separately (there is no categorization or grouping) and there
is no ranking of factors. The concept expressed is that an irreducible
level exists at which subjective trade-offs must be made and that a
systematic, organized process of data presentation is most appropriate.

12. Southeastern Wisconsin Regional Planning Commission. "Land Use Trans-
portation Study - Forecast and Alternative Plans. 1990." Vol. 2
Plan Report No. 7. June, 1966.

Various environmental objectives are stated. These are ranked in
order of importance for each situation, then weighted values are assigned
on a direct reverse listing of the numerical importance rank. Each of
the alternative projects or routes is then rated against the environmental
objectives--no particular rating value system is specified. The two num-
bers for rating and ranking are multiplied together for each objective,
and the resulting values for all the objectives are added for each alter-
native. These final values represent the evaluation of specific alterna-
tives against their achievement of the objectives and can be used for
comparison against each other.

In this method, the assignment of weights is arbitrary rather than
objective. Subjective judgments are required in ranking and in the
rating of alternatives against the objectives. Some measure of the
relative value of alternative plans is achieved, but impact itself is
not determined.

Checklists - Type C

12. Dearinger, J. A. "Esthetic and Recreational Potential of Small Naturalistic
Streams Near Urban Areas." Water Resources Institute, University of Kentucky
April, 1968.

This technique was designed for evaluating esthetic and recreational aspects of small streams. Environmental factors, such as water quality, wildlife, and scenic views, were weighted on a scale from 1 to 5 depending on their importance for types of potential recreational uses. hiking trails, canoeing areas, etc. In evaluating a location, a rating number is established for each particular environmental factor in each use category. This number is between 1 and 10 and is determined through a set value function (e.g., BOD and turbidity for water quality). The weighing and rating numbers are multipled for each factor and the results from all the factors added for each type of use. This final number is made a percentage of the number that would apply to the suitability of the location for a use if all conditions were optimum (all rating numbers equal to 10).

13. Orlob, G.T., et. al. "Wild Rivers: Methods for Evaluation." Water Resources Engineers, Inc. for the U.S. Department of the Interior. October, 1970.

Nonmonetary and intangible values are expressed in dollars, on the premises that such values are at least equal to the economic development benefits that are foregone in favor of preservation, and that nonmonetary benefits equal between 0.25 and 2.0 times monetary benefits. Environmental values can then be subjected to the benefit-cost analysis. The assumptions made in this method are arbitrary, and no provision is made for analyzing the nonmonetary environmental impacts of development. The evaluations required are very lengthy mathematical computations.

Interaction Matrices and Networks

for Impact Assessment

by

L W Canter*

Various methodologies for environmental impact analysis have been developed since the passage of the National Environmental Policy Act. There is no universal methodology due to the diversity of projects and predicted impacts encountered in agency-proposed actions This discussion is a presentation of principles and examples of two categories of methodologies, namely, interaction matrices (or simply, matrices) and networks

I. Definitions (1)

A. <u>Matrices</u> These methodologies incorporate a list of project activities in addition to a checklist of potentially impacted environmental characteristics. These two lists are related in a matrix which identifies and impacts Matrix methodologies may specify which actions impact which environmental characteristics or may simply list the range of possible actions and characteristics in an open matrix to be completed by the analyst

B <u>Networks</u> These methodologies work from a list of project activities to establish cause-condition-effect networks. They are an attempt to recognize that a series of impacts may be triggered by a project action.

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154

These approaches generally define a set of possible networks and allow the user to identify impacts by selecting and tracing out the appropriate project actions.

II. Leopold Interaction Matrix (2)

A. Principle of the Method

Basic principle is the use of a matrix with 100 different specified actions and 88 environmental items. An impact is identified at the interaction between an action and an environmental item. See Figure 1. List of actions and items in Table 1.

B. Interatctions

1. Described in terms of **magnitude** and **importance**.

2. Magnitude

a) related to extensiveness or scale

b) objective evaluation based on facts

c) scale from 1 to 10; 10 represents greatest magnitude; 1 represents lowest.

3. Importance

a) related to significance

b) subjective evaluation based on the judgment of interdisciplinary team

c) scale form 1 to 10; 10 represents most important, 1 the least important

C. Evaluation of the Leopold Interaction Matrix
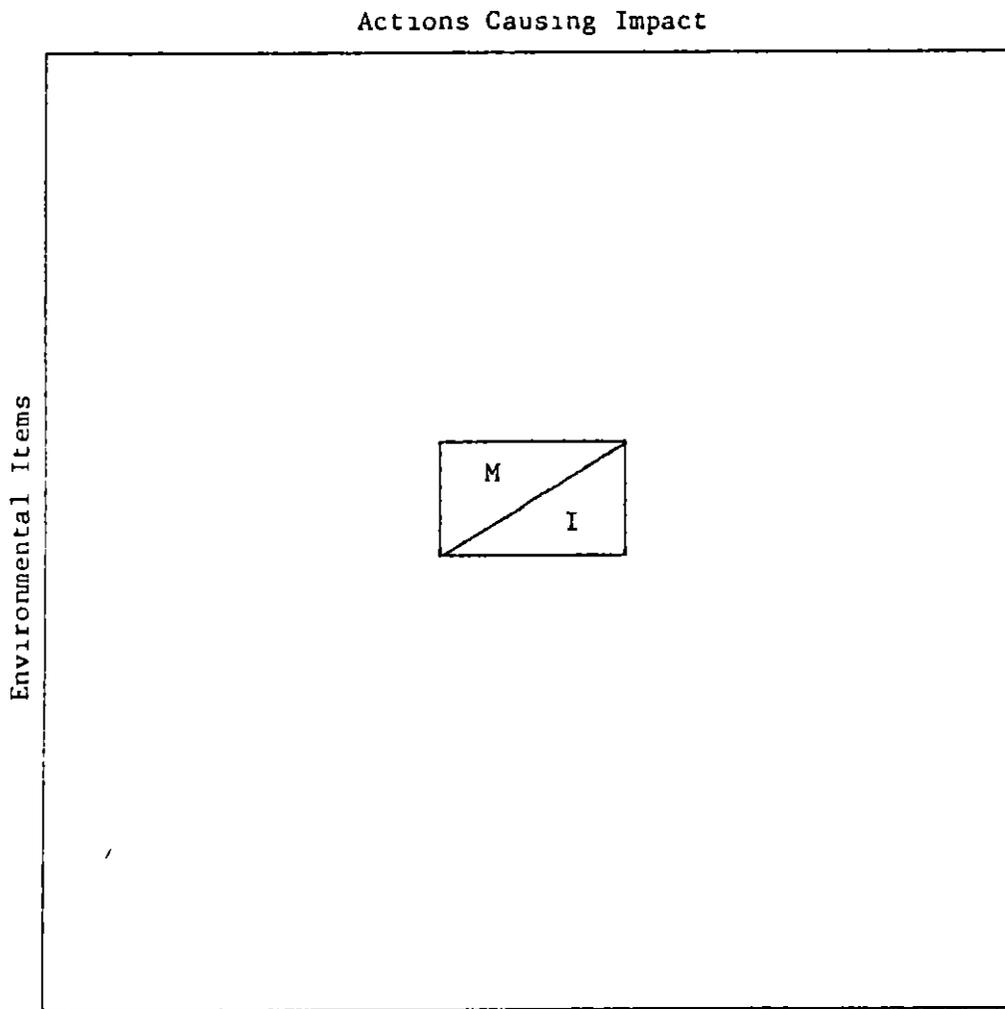
1. Can be expanded in either direction

2. Can be used as:

Actions Causing Impact

FIGURE 1   Leopold Interaction Matrix

TABLE 1   Actions and Items in Leopold Interaction Matrix

Actions			Environmental Items		
Category	No.	Description	Category	No.	Description
A. Modification of Regime	a.	Exotic Fauna Introduction	**A.** Physical and Chemical Characteristics		
	b.	Biological Controls			
	c.	Modification of Habitat	**1. Earth**	a.	Mineral Resources
	d.	Alteration of Ground Cover		b.	Construction Material
	e.	Alteration of Ground Water Hydrology		c.	Soils
				d.	Land Form
	f.	Alteration of Drainage		e.	Force Fields and Background Radiation
	g.	River Control and Flow Modification		f.	Unique Physical Features
	h.	Canalization	**2. Water**	a.	Surface
	i.	Irrigation		b.	Ocean
	j.	Weather Modification		c.	Underground
				d.	Quality
	k.	Burning		e.	Temperature
	l.	Surface or Paving		f.	Recharge
				g.	Snow, ice, and perma frost
	m.	Noise and Vibration	**3. Atmosphere**	a.	Quality (gases, particulates)
B. Land Transformation and Construction	a.	Urbanization		b.	Climate (micro, macro)
	b.	Industrial Sites and Buildings			
	c.	Airports		c.	Temperature
	d.	Highways and Bridges	**4. Processes**	a.	Floods
				b.	Erosion
	e.	Roads and Trails		c.	Deposition (Sedimentation, precipitation)
	f.	Railroads			

Actions			Environmental Items		
Category	No.	Description	Category	No.	Description
	g.	Cables and Lifts		d.	Solution
	h.	Transmission Lines, Pipelines and Corridors		e.	Sorption (ion exchange, complexing)
	i.	Barriers including Fencing		f.	Compaction and Settling
	j.	Channel Dredging and Straightening		g.	Stability (Slides, Slumps)
	k.	Channel Revertments		h.	Stress Strain (Earthquakes)
	l.	Canals		i.	Air Movements
	m.	Dams and Impoundments	B Biological Conditions		
	n.	Piers, Drawalls, Marinas, and Sea Terminals	1. Flora	a.	Trees
				b.	Shrubs
	o.	Offshore Structures		c.	Grass
				d.	Crops
	p.	Recreational Structures		e.	Microflora
				f.	Aquatic Plants
	q.	Blasting and Drilling		g.	Endangered Species
				h.	Barriers
	r.	Cut and Fill		i.	Corridors
	s.	Tunnels and Underground Structures	2. Fauna	a.	Birds
				b.	Land Animals Including Reptiles
C. Resource Extraction	a.	Blasting and Drilling		c.	Fish and Shellfish
	b.	Surface Excavation		d.	Benthic Organisms
				e.	Insects
	c.	Subsurface Excavation and Retorting		f.	Microfauna
				g.	Endangered Species
	d.	Well Dredging and Fluid Removal		h.	Barriers
				i	Corridors

Actions			Environmental Items		
Category	No.	Description	Category	No.	Description
	e.	Dredging	C. Cultural Factors		
	f.	Clear Cutting and Other Lumbering			
	g.	Commercial Fishing and Hunting	1. Land Use	a.	Wilderness and Open Spaces
				b.	Wetlands
D. Processing	a.	Farming		c.	Forestry
	b.	Ranching and Grazing		d.	Grazing
				e.	Agriculture
	c.	Feed Lots		f.	Residential
	d.	Dairying		g.	Commercial
	e.	Energy Generation		h.	Industry
	f.	Mineral Processing		i.	Mining and Quarrying
	g.	Metallurgical Industry	2. Recreation	a.	Hunting
				b.	Fishing
	h.	Chemical Industry		c.	Boating
	i.	Textile Industry		d.	Swimming
	j.	Automobile and Aircraft		e.	Camping and Hiking
	k.	Oil Refining		f.	Picnicking
	l.	Food		g.	Resorts
	m.	Lumbering	3. Aesthetic and Human Interest	a.	Scenic Views and Vistas
	n.	Pulp and Paper		b	Wilderness Qualities
	o.	Product Storage		c.	Open Space Qualities
E. Land Alteration	a.	Erosion Control and Terracing		d.	Landscape Design
				e.	Unique Physical Features
	b.	Mine Sealing and Waste Control		f.	Parks and Reserves
	c.	Strip Mining Rehabilitation		g	Monuments
				h	Rare and Unique Species or Ecos /Stems
	d.	Landscaping			
	e.	Harbor Dredging		i.	Historical or Archaeological Sites and Objects
	f.	Marsh Fill and Drainage			
				j.	Presence of Misfits

Actions			Environmental Items		
Category	No.	Description	Category	No.	Description
F. Resource Renewal	a.	Reforestation	4. Cultural Status	a.	Cultural Patterns (Life Style)
	b.	Wildlife Stocking and Management		b	Health and Safety
				c.	Employment
	c.	Ground Water Recharge		d.	Population Density
	d.	Fertilization Application	5. Man-Made Facilities and Activities	a.	Structures
				b.	Transportation Network (Movement, Access)
	e.	Waste Recycling			
G Changes in Traffic	a.	Railway		c.	Utility Networks
				d.	Waste Disposal
	b.	Automobile		e.	Barriers
	c.	Trucking		f.	Corridors
	d.	Shipping	D. Ecological Relationships Such As.	a.	Salinization of Water Resources
	e.	Aircraft			
	f.	River and Canal Traffic		b.	Eutrophication
				c.	Disease-Insect Vectors
	g.	Pleasure Boating		d.	Food Chains
	h.	Trails		e.	Salinization of Surficial Material
	i.	Cables and Lifts			
	j.	Communication		f.	Brush Encroachment
	k.	Pipeline		g.	Other
H Waste Replacement and Treatment	a.	Ocean Dumping	Others		
	b.	Landfill			
	c.	Emplacement of Tailings, Spoils, and Overburden			
	d.	Underground Storage			
	e.	Junk Disposal			
	f.	Oil Well Flooding			
	g.	Deep well emplacement			

Actions			Environmental Items		
Category	No.	Description	Category	No.	Description
	h.	Cooling Water Discharge			
	i.	Municipal Waste Discharge Including Spray Irrigation			
	j.	Liquid Effluent Discharge			
	k.	Stabilization and Oxidation ponds			
	l.	Septic Tanks, Commercial and Domestic			
	m.	Stack and Exhaust Emission			
	n.	Spent Lubricants			
I. Chemical Treatment	a.	Fertilization			
	b.	Chemical De-icing of Highways, etc.			
	c.	Chemical Stabilization of Soil			
	d.	Weed Control			
	e.	Insect Control (pesticides)			
J. Accidents	a.	Explosions			
	b.	Spills and Leaks			
	c.	Operational Failure			
Others					

a) gross screen for identification purpose

b) technique for visual display of impacts

3. Can be used for various temporal phases of the project under

   consideration:

   a) construction

   b) operation

   c) post-operation

4. Can be used for various spatial boundaries

   a) site

   b) region

5. Used to define three levels of impact

   a) major (important)

   b) intermediate

   c) minor

6. Can show plus or minus impacts

7. Summation of rows or columns might offer some insights, as well as

   product of magnitude and importance values

8. Very minimal focus on socio-economic considerations

III. Variations of Leopold Interaction Matrix

A. Airport Projects

   1. Examples of FAA interaction matrices are shown in Tables 2 and 3

      (3). It should be noted that the types of actions and the environ-

      mental items have been altered from the Leopold Interaction Matrix

      a) used basically for identification of impacts in terms of +, -,

         or ?

-9-

Prepared By:

Type of Environmental Consideration and Action / Impact Factor	Administrative decree FAA or OST	Highly Controversial (Environmental Basis)	Inconsistent with National Environmental Standards	Significant Adverse Impact	Section 4(f) - DOT Act	Section 16 - AAD Act	Section 106 - Historic Act	Airspace Design	Airspace Use	Airport Design	Airport Development	Airport Operation	Aircraft Design	Aircraft Development	Aircraft Operation	Facilities Design	Facilities Development	Facilities Operation	Aviation (General) Policy	Aviation (General) Plans	Medicine	R&D
Air Quality																						
Water Quality																						
Noise																						
Ground Water																						
Drainage/Sediment																						
Natural Resources																						
Ecological																						
Cultural																						
Aesthetic																						
Congestion																						
Divides Community																						
Disrupts Community																						
Housing Relocation																						
Land Use Compatibility																						
Economic																						
Safety																						

(Row labels grouped at left: "Environmental" for Air Quality through Land Use Compatibility; "Other" for Economic and Safety)

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NOTE 1. Check only items of interaction with +, -, or ? corresponding to positive, negative or unknown impacts respectively. Other subjective scales may be developed and used if described.

Table 3:   FAA Environmental Impact Identification Matrix

Actions Causing Environmental Impact		Existing Factors – of the Environment	
Category	Action	Category	Factor
1. Land Alteration/ Construction	Landscaping Flora/Fauna Burning Filling Dredging Clearing Drainage Land Surfacing Excavation Road/Trails Airports Transmission Lines Pipelines Barriers Piers, Seawalls Structures Antenna	Quality Standards Resources Socio-Economics	Air Quality Groundwater Quality Surface Water Quality Soil Quality Landuse Planning Ambient Noise Airspace Mineral Scientific Historic Cultural Scenic Recreation Land Public Health Safety Employment Public Services
2. Traffic Changes	Vehicles Aircraft Pipeline Communication Marine		Mobility Congestion Housing Displace People Disrupt Community Tax Base Racial Ethnic
3. Safety/Accidents	Operational Failure Explosions Leaks Radiation	Ecological/ Biological	Disease Vectors Salinization Eutrophication Crops Trees
4. Resource Use and/or Development	Recycling Groundwater Wildlife Reforestra- tion Farming A/C Manufac- turing	Areas of Significance	Ground Cover Rare Species Animals, Land Marine Life Aves International Federal Regional

15

Actions Causing Environmental Impact		Existing Factors of the Environment	
Category	Action	Category	Factor
	Power/Energy Use		State
	Manpower		Local
	Finance		
5. Use of Wastes and Chemical	Emissions, Vehicle		
	Emissions, Aircraft		
	Chemical Dispersal		
	Need Control		
	Insect Control		
	Deicing		
	Soil Stabilization		
	Sewage Disposal		
	Junk		
	Oils/Lubricants		
6. Activity Phase	Needs/Priority		
	Planning/Design		
	Siting		
	Construction		
	Operation		
7. Other			

b) other subjective scales may be developed and used if described

2. Another example of an airport matrix is shown in Table 4 (4)

B. Highway Projects

1. Table 5 contains an interaction matrix developed for highway
projects (5)

2. The matrix in Table 5 is used only for identification of impacts

C. Earthfill Dam (6)

1. Table 6 contains an interaction matrix for an earthfill dam

2. An indication of the potential impact of each alternative on various environmental factors is shown. There are 11 possible impacts ---
neutral, 5 ranges of beneficial, and 5 ranges of detrimental.

D. Short Versions of Leopold Interaction Matrix (6)

1. Table 7 contains an environmental analysis matrix for a coal mine

2. Table 8 is for a generation plant, county road, and railroad

3. Table 9 is for a water supply system

4. Table 10 is for a transmission line

E. Construction Planning Interaction Matrix (7)

1. Table 11 shows a construction phase interaction matrix developed
by the Corps of Engineers

2. Alternate methods of accomplishing various construction operations
are presented

F. Interaction Matrix with Consideration of Probability of Impact (6)

1. Table 12 was developed for a phosphate mining lease in California

2. Each impact is assigned a magnitude and importance on a scale from
1 to 3 (1 represents least impact, 3 represents greatest impact).
In addition, each impact is assigned a probability of occurrence

-13-

Table 4: Airport Interaction Matrix

Environmental Actions		Environmental Items	
Phase	**Action**	**Category**	**Item**
<u>Planning</u>	a) Field Surveys b) Rezoning c) Siesmology d) Advertising e) Land Aquisi- tion	<u>Physical Aspects</u>	a) Location b) Topography c) Temperature d) Wind e) Rain f) Drainage g) Erosion

<u>Construction</u>	a) Clearing
	b) Paving
	c) Sewage Dispos-
	    al
	d) Blasting
	e) Grading
	f) Construction
	    Traffic
	g) Fencing
	h) Importing and
	i) Dep. Materials
	i) Burning
	j) Excavation
	k) Soil Stabilization
	l) Access Roads
	m) Equipment
	n) Water Lines
	o) Earth Fill
	p) Revegetation
	q) Cleanup
	r) Buildings
			h) Runoff
			i) Groundwater
			j) Surface Water
			k) Mineral Resources
			l) Water Quality
			m) Noise
			n) Air Quality
			o) Geology
			p) Soil

		<u>Biological Aspects</u>	a) Rookeries b) Insects c) Shrubs and Trees d) Grass Cover e) Forage f) Endangered Flora g) Endangered Fauna h) Wildlife i) Fish

<u>Operations-Direct</u>	a) Air Approach
	b) Air Traffic
	    Clear
	c) Passenger Traf-
	    fic
	d) Freight Traf-
	    fic
	e) Fuel Transpor-
	    tation
	f) Navigation
	g) Radar
	h) Communications
	i) Security
	j) Lighting
	k) Services-Food,
	    etc.
		<u>Socio-Economic Aspects</u>	a) Safety Hazards
			b) Transportation
			c) Population
			d) Recreation
			e) Public Health
			f) Housing
			g) Economy
			h) Agriculture
			i) Industry
			j) Land Use
			k) Taxes
			l) Real Estate
			m) Police Protec-
			    tion
			n) Fire Protection
			o) Telephone
			p) Sewers
			q) Water

Environmental Actions		Environmental Items	
Phase	Action	Category	Item
	1) Fuel Storage		r) Electricity s) Natural Gas
Operations-Indirect	a) Commerical Dev. b) Industrial Dev. c) Regional Dev. d) Housing e) Public Facili- ties	Cultural Aspects	a) Historic Sites b) Archeology c) Paleontology d) Aesthetics

Table 5: Highway Intereaction Matrix

Actions Which May Cause Impact			Environmental Conditions		
Category	Sub-Category	Action	Category	Sub-Category	Action

A. Elements of Design and Location

  1. Modification of Regime

    a. Modification of Habitat
    b. Alteration of Groundwater Hydrology
    c. Canalization
    d. Irrigation
    e. Surfacing and Paving

  2. Land Transformation and Construction

    a. Highways and Bridges
    b. Roads and Trails
    c. Barriers Including Fencing
    d. Channel Dredging and Straightening
    e. Channel Revetments
    f. Dams-Impoundments
    g. Piers-Seawalls
    h. Recreational Structures
    i. Cut and Fill
    j. Tunnels and Underground Structures
    k. Erosion Control
    l. Landscaping
    m. Harbor Dredging
    n. Marsh Fill and Draining
    o. Scenic Waysides
    p. Junkyard and Billboard Removal

  3. Well Drilling

  4. Resource Renewal and Protection

    a. Reforestation
    b. Scenic Strip Acquistion

  5. Changes in Traffic

    a. Railway
    b. Automobile
    c. Trucking

A. Physical and Chemical Characteristics

  1. Earth

    a. Mineral Resources-Precious
    b. Mineral Resources-Common
    c. Soils
    d. Land Form

  2. Water

    a. Surface
    b. Ocean-Estuaries
    c. Underground
    d. Snow-Ice
    e. Recharge-Percolation
    f. Qualtiy
    g. Temperature

  3. Atmosphere

    a. Quality
    b. Climate
    c. Temperature

  4. Processes

    a. Floods
    b. Erosion (Air or Water)
    c. Deposition (Air or Water)
    d. Solution
    e. Compaction and Settling
    f. Stability (Slides and Stumps)
    g. Air Movements
    h. Fire
    i. Evaporation

B. Biological Conditions

  1. Flora

    a. Trees
    b. Shrubs
    c. Grass
    d. Crops

Action Which May Cause Impact			Environmental Conditions		
Category	Sub-Category	Action	Category	Sub-Category	Action

d River and Canal Traffic		e. Microflora
e. Pleasure Boating		f. Aquatic Plants
f. Trails		g. Endangered Species
g. Communication		h. Barriers
h. Pipeline		i. Corridors

B. During Construction

1. Modification of Regime

a. Exotic Flora and Fauna Introduction
b. Biological Controls
c. Alteration of Ground Cover
d. Alteration of Drainage
e. River Control and Flow Modification
f. Burning

2. Land Transformation and Construction

a. Blasting and Drilling
b. Marsh Fill and Drainage
c. Clearing and Grubbing
d. Dams-Impoundments
e.

3. Resource Extraction

a. Blasting and Drilling
b. Surface Excavation
c. Subsurface Excavation
d. Well Drilling and Fluid Removal
e. Dredging

4. Changes in Traffic

a Railway
b. Automobile
c Trucking
d. River and Canal Traffic
e. Pleasure Boating
f. Trails
g. Communication
h. Pipeline

2. Fauna

a. Birds
b. Land Animals
c. Fish and Shellfish
d. Other Aquatic Organisms
e. Insects
f. Microfauna
g. Endangered Species
h. Barriers
i. Corridors

C. Cultural Factors

1. Land Use

a. Wilderness
b. Open Space
c. Wetlands
d. Forestry
e. Grazing
f. Agriculture
g. Residential
h. Commericial
i. Industrial
j. Lakes and Rivers

2. Recreation

a. Hunting
b. Fishing
c. Boating
d. Swimming
e. Camping
f Hiking
g. Picnicking
h. Resorts
i. Winter Sports
j. Rockhounding

Actions Which May Cause Impact			Environmental Conditions		
Category	Sub-Category	Action	Category	Sub-Category	Action

5. Waste Emplacement Treatment

  a Landfill
  b. Emplacement of Tailings, Spoil and Overburden
  c. Liquid and Exhaust Discharge
  d. Stack and Exhaust Emission
  e Spent Lubricants

6. Chemical Stabilization of Soil

7. Accidents

  a. Explosions
  b. Spills and Leaks
  c. Operational Failure

C. Operation

  1. Waste Emplacement and Treatment

   a. Liquid Effluent Discharge
   b. Septic Tanks
   c. Stack and Exhuast Emission

  2. Chemical Treatment

   a Fertilization
   b. Chemical Deicing
   c. Weed Control
   d. Insect Control

  3. Accidents

   a. Explosions
   b. Spills-Leaks
   c. Operational Failures

3. Aesthetics and Human Interest

  a. Scenic Views and Vistas
  b. Wilderness Qualities
  c. Open Space Qualities
  d. Landscape Design
  e. Unique Physical Features
  f. Parks and Reserves
  g. Monuments
  h. Rare or Unique Species or Ecosystems
  i. Historical or Archeological Sites and Objects
  j. Presence of Incompatible Features

4. Cultural Status

  a. Cultural Patterns
  b. Health
  c. Population Density
  d. Institutions
  e. Minority Groups
  f. Economic Groups

5. Manmade Facilities and Activities

  a. Structures
  b. Transportation
  c. Utility Networks
  d. Waste Disposal
  e. Barriers
  f. Corridors
  g. Governmental Activities

Table 6

POSSIBLE ALTERNATIVE ACTIONS

Legend	
Detriments	
Neutral	N
Very Slight	vSl-
Slight	Sl-
Moderate	M -
Severe	Se-
Very Severe	vSe-
Benefits	
Neutral	N
Very Slight	vSl+
Slight	Sl+
Moderate	M +
High	H +
Very High	vH+

	Proposed Action	No Action (Alternative One)	Expansion of Existing Source (Alternative Two)	Impoundment on Ironstone Creek (Alternative Three)	Alternate Sites on Trout Run (Alternative Four)	Diversion Dam on Trout Run (Alternative Five)	Importation of Water Supply (Alternative Six)	Groundwater (Alternative Seven)
Physical and Chemical Characteristics								
Earth	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	vSl-
Water	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	Sl-
Atmosphere	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	N
Biological Conditions								
Flora	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	vSl-
Fauna	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	vSl-
Cultural Factors								
Land Use	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	vSl-
Government	N	N	N	N	N	N	N	N
Recreation	vSl-	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-
Esthetics	Sl-	N	Sl-	vSl-	Sl-	vSl-	vSl-	N
Cultural Status	N	N	N	N	N	N	N	N
Non-Made Resources	vSl-	N	vSl-	vSl-	vSl-	vSl-	vSl-	vSl-

ECOLOGICAL RELATIONSHIPS

160

TABLE 7: Interaction Matrix for Coal Mines

Proposed Actions Category Action	Environmental Condition Category Sub-Category Item

B. Land Transformation - Industrial
    and Construction   Sites
 	
    - Highways
      and
      Bridges
 	
C. Resource Extraction - Blasting
      and
      Drilling
 	
    - Surface
      Excavation
 	
E. Land Alteration - Strip Mining
      Rehabilitation
 	
H. Waste Emplacement - Liquid
      Effluent
      Discharge
	A. Physical and Chemical
	   Characteristics
	   1. Earth IA1.c Soils
	   2. Water IA2.a Surface Water
	                         Quality
	   3. Atmosphere IA3.a Quality
	   4. Processes IA4.g Stability
	
	B. Biological Conditions
	   1. Flora IB1.b Shrubs
	             IB1.c Grass
	   2. Fauna IB2.a Birds
	             IB2.b Land Animals
	
	C. Cultural Factors
	   1. Land Use IC1.d Grazing
	   2. Recreation IC2.a Hunting
	   3. Aesthetics IC3.a Scenic Views
	      and Human and Vistas
	      Interest IC3.b Wilderness
	                             Qualities
	                  IC3.c Open Space
	                             Qualities
	   4. Cultural IC4.a Cultural Patterns
	      Status IC4.c Employment
	   5. Man Made IC5.g Interpretive
	      Facilities Education
	      and Activities

TABLE 8.   Interaction Matrix for Generation Plant, County Road, and Railroad

Actions Which May Cause Impacts		Environmental Conditions		
Category	Action	Category	Sub-Category	Action
B. Land Transformation and Construction		A. Physical and Chemical Characteristics		
	b. Industrial Sites and Buildings		1. Earth IA1.a	Mineral Resources
			IA1.b	Construction Materials
	d. Highways and Bridges		2 Water IA2	Surface Water Quality
	f. Railroads			
D. Processing			3. Atmosphere IA3 a	Atmospheric Quality
	e. Energy Generation		IA3.b	Climate
G. Changes in Traffic		B. Biological Conditions		
	a. Railway		1. Flora IB1.b	Schrubs
	b. Automobile		2. Fauna IB2.a	Birds
	c. Trucking		IB2.b	Land Animals
H. Waste Emplacement and Treatment			IB2.e	Insects
			IB2.f	Microfauna
	c. Emplacement of Tailings, Spoil and Overburden	C. Cultural Factors		
			1. Land Use IC1.d	Graz ng
			IC1.g,f,h	Resi-dential Commercial and Industrial
	h. Cooling Water Discharge			
	j. Liquid Effluent Discharge		3. Aesthetics and Human Interest IC3.a	Scenic Views and Vistas
	e. Septic Tanks		IC3.i	Historical and Archaeological
	j. Stack Emissions			
			4. Cultural Status IC4.c	Employment
			IC4.d	Population Density
			5. Man-Made Facilities IC5.b	Transportation Network

TABLE 9   Interaction Matrix for Water Supply System

Proposed Actions		Environmental Condition		
Category	Action	Category	Sub-Category	Item
A. Modification of Regime	- Modification of Habitat	A. Physical and Chemical Characteristics		
	- Alteration of Ground Cover	1. Earth	IA1.b	Construction Material
	- Alteration of Drainage		IA1.c	Soils
	- Noise and Vibration	2. Water	IA2.a	Surface Water
B. Land Transformation and Construction	- Industrial Sites and Buildings	4. Processes	IA4.b & c	Erosion and Deposition
	- Roads and Trails	B. Biological Conditions		
	- Cables and Lifts	1. Flora	IB1	Flora
	- Transmission lines and Corridors	2. Fauna	IB2.a	Birds
	- Dams and Impoundments		IB2.b and c	Land Animals and Fish
	- Cuts and Fills	C. Cultural Patterns		
C. Resource Extraction	- Fluid Removal	1. Land Use	IC1.d	Grazing
			IC1.f and g	Residential and Commercial
E. Land Alteration	- Erosion Control			
	- Rehabilitation	2. Recreation	IC2.b	Fishing
G. Changes in Traffic	- Automobile		IC2.c	Boating
			IC2.F	Picnicking
H. Waste Emplacement and Treatment	- Emplacement of Soil and Overburden	3. Aesthetics and Human Interest	IC3.a	Scenic Views and Vistas
			IC3.d	Landscape Design
			IC3.j	Presence of Misfits
I. Chemical Treatment	- Chemical Treatment of Water	4. Cultural Status	IC4.a	Cultural Patterns
			IC4.b	Health and Safety
			IC4.c	Employment
J. Accidents	- Spills and Leaks	5. Man-Made Facilities	IC5.b	Transportation Networks

TABLE 10   Interation Matrix for Transmission Lines

Actions Which May Cause Impact		Environmental Condition		
Category	Action	Category	Sub-Category	Action
A Modification of Regime	c. Modification of Habitat	A. Physical Characteristics		
			1. Earth	b Erosion
B. Land Transformation and Construction	e. Roads and Trails			c. Deposition
	h. Transmission Lines and Corridors	B. Biological Conditions		
			1. Flora	Flora
C Changes in Traffic	h. Trails		2. Fauna	a. Birds
				b. Land Animals
J. Accidents	c. Operational Failure	C. Cultural Factors		
			1. Land Use	c Forestry
				d. Grazing
				e. Agriculture
				h. Industrial
			2. Recreation	a. Hunting
			3. Aesthetics and human Interest	a. Scenic Views and Vistas
				b Wilderness Qualities
				c Open Space
				f. Parks and Reserves
				ı. Historical and Archaeological
			4. Cultural Status	b Health and Safety
				c. Employment
			5. Man-Made Facilities	c Utility Net
			6. Other	Fire Protection

Table 11   Construction Planning Interaction Matrix

Actions		Impacted Elements of the Environment on the Ecosystem	
Operations Sub-Operation	Alternative Methods of Accomplishment	Category	Element
Site Access		Air	
a. Rail	Existing, New, Permanent, Temporary	a. Gases b. Particulates	
b. Road	Unimproved, Stabilized Soil, Gravel Bituminous	c. Odors d. Toxics	
c. Water	Fords, Bridges, Culverts, Ferries, Ships, Docks	Surface Water a. Physical b. Chemical	
d. Air	Landing Strips, Helipads	c. Biological d. Toxic	
Preliminary Works		Ground Water	
a. Asphalt Plant	Hot Mix, Cold Mix, Continous Flow, Batch	a. Physical b. Chemical c. Biological d. Toxic	
b. Canteen	Mobile, Fixed		
c. Concrete Batch Plant	Bag, Bulk, Non-Tilting Drum, Pan Mixer, Continous Mixer, Split Drum	Noise a. Nuisance to Workers at Site b. Nuisance to Community c. Health Hazards to Workers d. Health Hazards to Community	
d. Crushing & Screening Plant	Jaw Crusher, Granulator, Gyrotary Crusher, Impact Breaker, Roll Crusher, Grizzles Revolving Screen, Vibrating Screen	Land a. Soils b. Land Form c. Unique Physical Features	
e. Field Maintenance Facility	Wash Racks, Oil & Lubrication, Repair	Flora a. Trees b. Shrubs	
f. Field Testing Laboratory	Soil, Concrete, Steel, Fixed, Mobile	c. Grass-Natural Ground Cover d. Crops e. Microflora	

-24-

Actions		Impacted Elements of the Environment on the Ecosystem	
Operation Sub-Operation	Alternative Methods of Accomplishment	Category	Element
g. Fuel Storage & Dispensing	Diesel, Gas, Oil Fixed, Mobile		f. Aquatic Plants g. Endangered Species
h. Fuel Laundry	Contract, Self-Service	Fauna	
i. Medical			a. Birds
j. Mess Hall	On-site Preparation Off-site Preparation		b. Land Animals Including Reptiles c. Fish & Shellfish d. Insects
k. Offices	Fixed, Mobile		e. Microfauna f. Endangered Species
l. Quarters	Fixed, Mobile		g. Recreation
m. Stores	Fixed, Mobile		h. Aesthetic i. Human Interests
n. Storage Yards			j. Economic
		Social	
			a. Housing b. Education-School System c. Health & Welfare d. Community Structure e. Transportation f. Chain Reactions

Table 12   Summary Estimated Magnitude. Importance and Probability of Possible Environmental Impacts from the Proposed Action

NEGATIVE IMPACTS

Resources Subject to Impact	Extraction			Processing			Transportation		
	Magnitude	Importance	Probability	Magnitude	Importance	Probability	Magnitude	Importance	Probability
A. Rare or Unique Resources:									
(1) California Condor	2	3	2	U	U	U	2	3	2
(2) Indian Artifacts	U	U	U	U	U	U	U	U	U
B. Water:									
(1) Quality	2	3	1	2	3	1	2	2	1
(2) Quantity	2	3	2	2	3	2			
C. Wildlife:									
(1) Deer, rabbits, quail, pigeon, etc.	1	1	3	1	1	3	1	1	3
(2) Fish	2	2	1	2	2	1	1	2	1
D. Recreation:									
(1) Campsites	3	3	3	1	2	3	2	2	3
(2) Trails	3	3	3						
(3) Recreation Driving							2	2	3.
(4) Vistas and Solitude	2	2	3	2	2	3	2	2	3
(5) Hunting	1	1	3	1	1	3			
E. Vegetation									
(1) Brush, trees and grass	2	1	3	3	1	U			
F. Air:									
(1) Quality	1	1	3	2	2	U	1	1	3
(2) Noise	1	2	3	1	1	3	1	2	3
G. Community Services	1	1	3	1	1	3	1	1	3
POSITIVE IMPACTS									
A. Protection from Wild Fire	2	2	3	2	2	3			

on a scale from 1 to 3 (1 represents low probability, 3 represents high probability)

G. Interaction Matrix with Consideration of Areal Extent of Impact (6)

1. Table 13 was developed for an off-shore oil and gas lease

2. Impacts are expected to occur from either the structures (drilling platforms) or oil spills. The importance of the impacts (IM) are assigned, as well as their proximity (PR) to significant resource factors

3. Impact Factor - (IM)(PR)

H. Interaction Matrix with Consideration of Impact Reversibility (6)

1. Table 14 shows a summary of an interaction matrix which includes reversible/irreversible/irreversible impacts, and community/ regional impacts.

2. Severity of the impact is shown in four categories.

III. Moore Environmental Impact Matrix (8)

A. Basis of Matrix

1. Moore developed a general guide to the relationship between typical manufacturing activities and their potential ultimate impact on the three regions of the Delaware coastal zone. It's primary orientation is toward the review of impact statements.

2. The three regions of the coastal zone, based on present land use and general goegraphic characteristics, are.

   a) Subregion One - Area From the Chesapeake and Delaware Canal North to the Pennsylvania Line

   This subregion is already heavily industrialized,

Table 13: Analysis of Possible Adverse Environmental Impact of South Marsh Island

Lease Area and Block
South Marsh Island
North Addition
Block 232

Tract Data:
Statute Miles from Shore ___14___
Water Depth - Feet ___10___
Est. Type of Production ___Oil & Gas___

SIGNIFICANT RESOURCE FACTORS	IMPACT FACTORS					
	Structures			Oil Spills (1000± bbl)		
	IM	PR	F(ST)	IM	PR	F(OS)
Natural Resource Systems· Refuges/Management Areas	20	00	0	100	06	60
Estuary/Marsh/Nursery Areas	20	00	0	100	05	50
Biota Seaward of Estuary/Nursery Areas	0	10	0	40	10	40
Beaches	40	00	0	80	05	40
Coastal Activities/Multiple Use Shipping	80	00	0	20	00	0
Recreation (Outdoor)	40	00	0	80	00	0
Commercial Fishing	80	10	80	80	10	80
Sport Fishing	0	10	0	80	05	40

Legend.   IM=Importance   F(ST)=Impact Factor - Structures
          PR=Proximity   F(OS)=Impact Factor - Oil Spills
          NCG-Not Computed for Gas only Blocks

Table 14: Interaction Matrix for Impact Reversibility

KEY			CORRIDORS		
			A SAUGUS MARSH	**B** BOSTON & MAINE RIGHT-OF-WAY	**C** MILL CREEK

KEY

SCALE OF IMPACT
- ❏ REVERSIBLE COMMUNITY
- ▣ IRREVERSIBLE COMMUNITY
- ○ REVERSIBLE REGIONAL
- ⊕ IRREVERSIBLE REGIONAL

SEVERITY OF IMPACT
- (0) IMPERCEPTIBLE
- (1) MINOR ADVERSE
- (2) MODERATE ADVERSE
- (3) SEVERE ADVERSE

		A SAUGUS MARSH	B BOSTON & MAINE RIGHT-OF-WAY	C MILL CREEK
B	PHYSICAL ALTERATION	○ (2)	▣ (2)	▣ (1)
C	NONCONFORMITY WITH EXISTING ENVIRONMENT	⊕ (3)	❏ (2)	❏ (0)
D	PHYSICAL SEPARATION	○ (3)	❏ (1)	❏ (0)
E	DISRUPTION OF ACCESS	○ (2)	❏ (1)	❏ (0)
F	DISRUPTION OF AMBIENT ENVIRONMENT	○ (3)	▣ (2)	❏ (1)
G	ACCESS INDUCED DEVELOPMENT	○ (3)	❏ (1)	❏ (0)
4(F) LANDS	DIRECT IMPACTS	SULLIVAN PLAY-GROUND	PAUL REVERE PARK & PLAY-GROUND	REVERE BEACH PARKWAY
	INDIRECT IMPACTS	ARCADIA, DOUGLAS & BATES STREET, SULLIVAN PLAYGROUNDS		

IMPACT BY CORRIDOR	MODERATE ADVERSE	MODERATE ADVERSE	IMPERCEPTIBLE

MODERATE ADVERSE

particularly around Delaware City, New Castle, and the
general Wilmington Area Much of the natural coastal zone
has already been appropriated for manufacturing uses. The
southern half of Subregion One, however, does contain some
tidal marshes. The general environment of this subregion
if typical of heavy manufacturing areas with the attendant
air/water degradation, noise,and aesthetic deterioration.
Water quality in the lower reaches of the Delaware River
is affected by discharges both from the Delaware area as
well as further up stream in the heavily industrial Phila-
delphia - New Jersey areas. This area also holds the
greatest overall promise for future industrial location
and expansion due to the proximity to regional markets,
transportation systems, and developed labor markets.

b) Subregion Two - Area From and Including the Chesapeake and
    Delaware Canal to but not Including the City of Lewes

        This area of the Coastal Zone consists of several thou-
    sand acres of private, state, and Federal wildlife refuges.
    There is some recreational development, though generally
    the shoreline and mud flats along the bay are not conducive
    to this typs of activity. The balance of the area is in
    woodlands and farms. The area is generally untouched by the
    impacts of industrial and manufacturing activity other than
    the indirect affects due to air and water pollution in the
    upper Delaware of areas adjacent to the Coastal Zone.

c) Subregional Three - Area From and Including the City of Lewes South of the Maryland State Line

This area is an important regional recreation attraction with fine beaches and intensive development for seasonal visitors. Some manufacturing activity takes place in the area, but not enough to alter significantly the environmental characterisitics of the subregion. The most significant environmental threat to this area is from overintensive recreation development, a problem beyond the scope of the present study. This recreation development has a potential for significantly altering remaining wildlife and fishery habitat in the area, as well as the aesthetic and human environment.

In all of the three subregions, historical/cultural sites and areas are important. Particularly noteworthy are the towns of New Castel in Subregion One and Lewes in Subregional Three. There are scattered pre-revolution homes and mansions in Subregion Two.

3. The basic philosophy of the method is that a meaningful analysis of manufacturing environmental impacts must ultimately be based on determination of direct and indirect impact on other human uses. Thus the matrix developed related manufacturing related alternations in the coastal environment to potential deterioration in opportunities for important human activities characteristic of the subregions of the Coastal Zone

4. The primary cause of change is the physical/biochemical alteration resulting from construction and operation of manufacturing

-31-

activities. Secondary causes of impact can also be attributed
to the supporting services, residential and other activities
that arise due to manufacturing location.

B. Conceptual Framework

1. Figure 2 depicts the generalized flow of manufacturing related
events that ultimately impact on human uses of the coastal
environment.

2. The nature of the relationships depicted in Figure 2 , is es-
sentially as follows. Construction and operation of a manufact-
uring facility (Box #1) leads initially to an alteration in
physical/biochemical parameters of the environment. These include
air quality, water quality, and areal extent of fish and wildlife
habitat and frequency and intensity of noise. Manufacturing
activity also leads to direct aesthetic effects (Box #3) asso-
ciated with the appearance of its various structures, smoke, and
other associated activities. Manufacturing activity also can
lead to an increase in regional population, change in demographic
characteristics and a general increase in demands for community
infrastructure (Box #4). Finally, manufacturing activity can
lead directly to effects on the social/human environment in terms
of altering work patterns and general life style demands of the
labor force (Box #5). Alterations in physical/biochemical para-
meters (Box #2) will lead to effects on coastal ecology (Box #7)
both directly and over time through complex ecological interac-
tions   Alterations in physical/biochemical parameters will also
have certain effects of aesthetic attributes (Box #3). Finally,

-32-
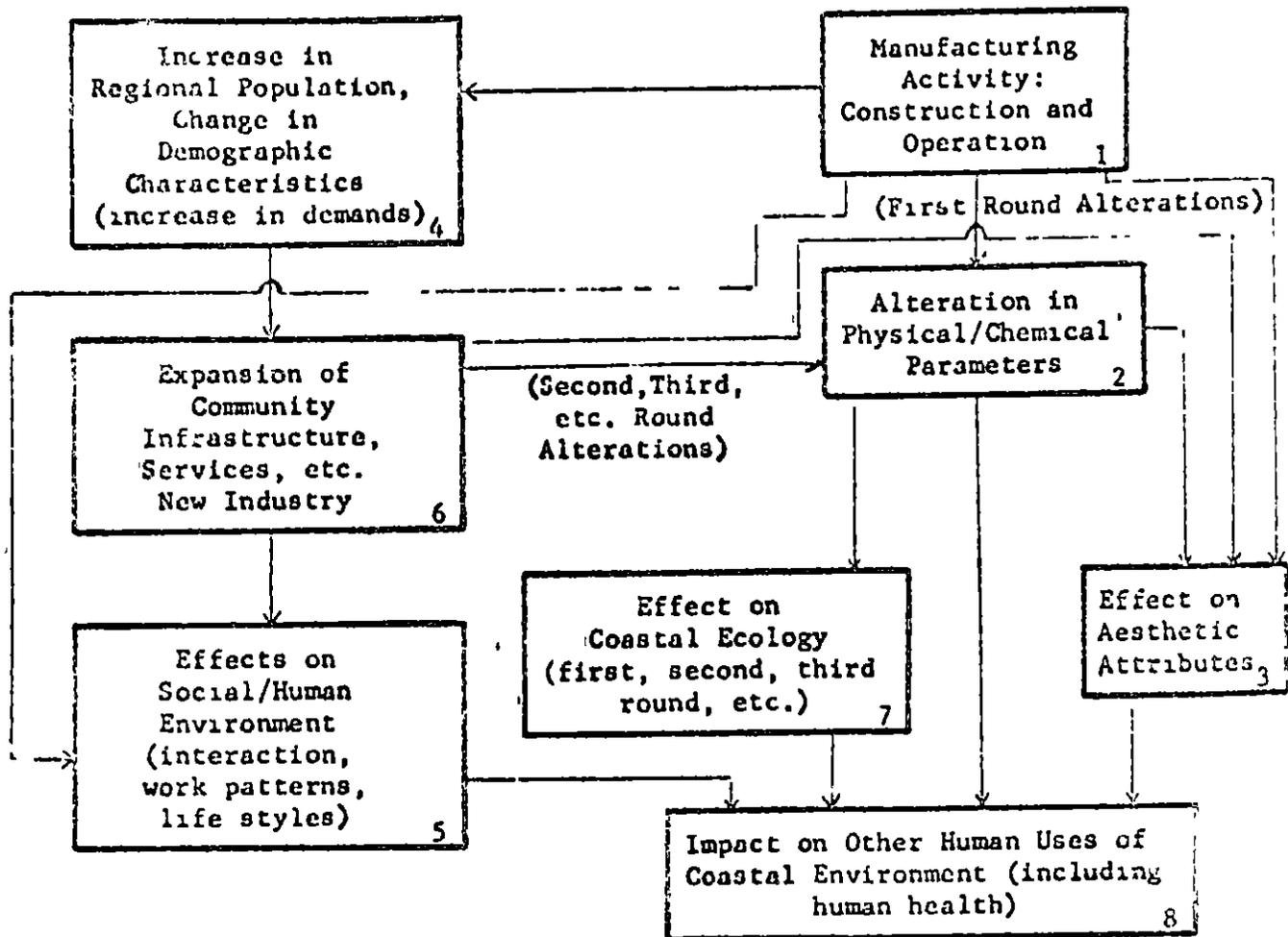
FIGURE 2: SCHEMATIC OF MANUFACTURING IMPACT
ON OTHER USES OF THE COASTAL
ENVIRONMENT

the alterations of physical/biochemical parameters will have direct impacts on human health and other uses of the coastal environment (Box #8). Increase in demand for community infrastructure, services and other related activity will result in expansion of these public facilities (Box #6). Expansion of these facilities will in turn create a second round, etc. series of alterations on the physical/biochemical parameters (Box #2) as well as on aesthetic attributes (Box #3). Finally, effects on coastal ecology (Box #7), effects on aesthetic attributes (Box #3), and effect on the social human environment (Box #5) will all combine along with alterations in the physical/biochemical parameters (Box #2) to impact and affect other human uses (including human health) of the coastal environment (Box #8).

3. It is this series of relationships which the environmental impact matrix attempts to describe in some detail.

C. The Matrix

1. Figure 3 presents the generalized relationships contained in the Moore environmental impact matrix. The matrix is divided into four separate lists of distinct or reasonably distinct categories of manufacturing, environmental, and human use interaction characteristics and two categories of impact These are·

Interaction Categories

    (I)   Manufacturing and Related Activities
   (II)   Major Environmental Alterations
 (III)   Major Environmental Effects
  (IV)   Human Uses Affected

Figure 3   Moo.   ~eraction Matrix
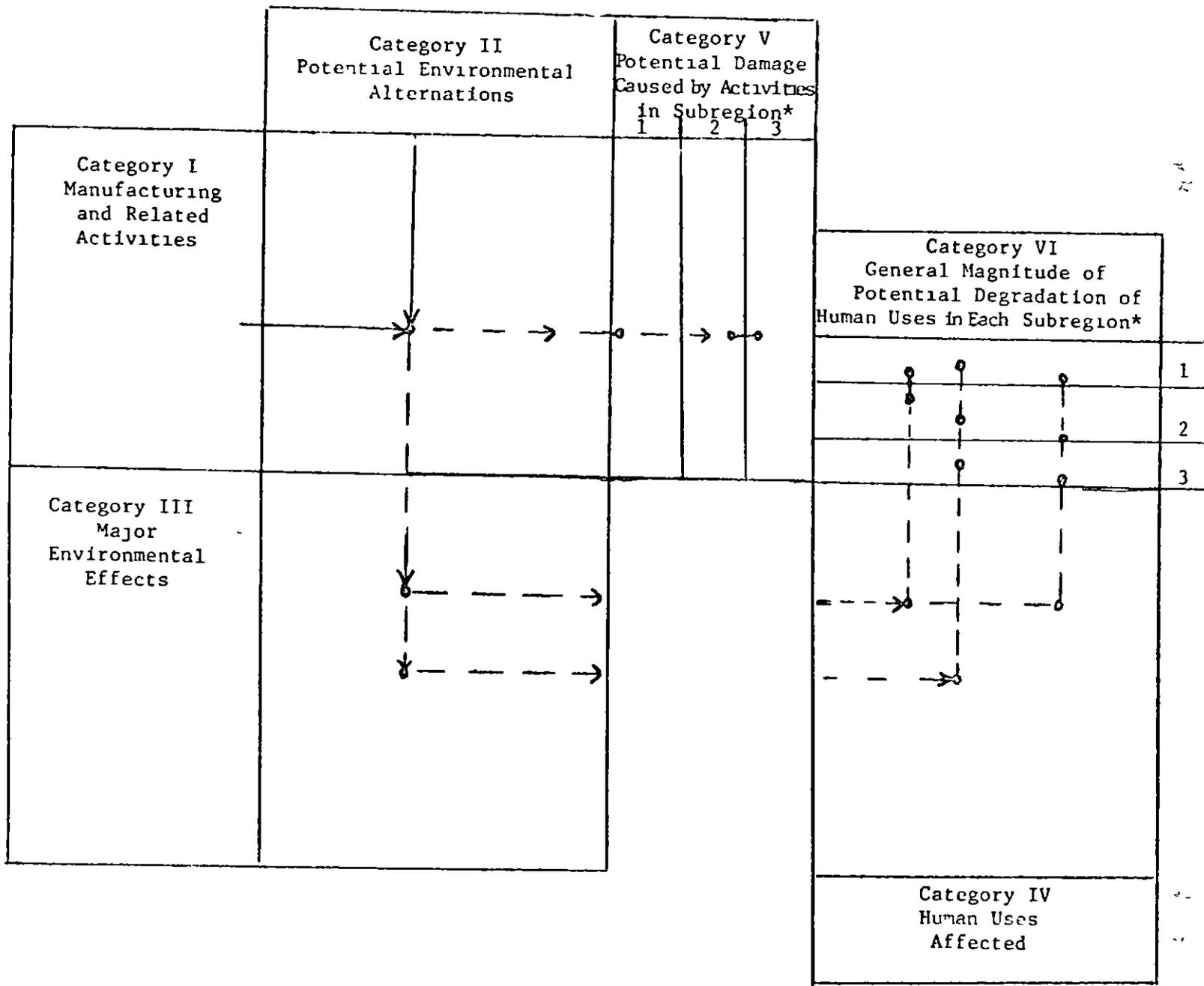
* Each subregion has a four-level scale (negligible, low, moderate, high)

Impact Categories

    (V)   Potential Damage Caused by Activities
   (VI)   General Magnitude of Potential Degradation on
          Human Uses.

2. The impact categories are included in the matrix to aid in

evaluating the relative magnitude and importance of specific

activities and environmental effects.

3. Category V is an evaluation of the potential of manufacturing

and related activities (Category I) for causing environmental

damage in each subregion of the Coastal Zone. Each manufactur-

ing activity is rated on a four level scale (negligible, low,

moderate, high) as to its potential for environmental damage.

4. Category VI is an evaluation of the level of potential impact

on human uses (IV) resulting from major environmental effects

(III). Impacts are evaluated for each subregion on a four

level scale (negligible, low, moderate, high).

5. The individual breakdown of the interaction categories is shown

in Table 15 for manufacturing and related activities (Category I),

Table 16 for major environmental alterations (Category II),

Table 17 for major environmental effects (Category III), and

Table 18 for human uses affected (Category IV).

6. The general flow of relationships in the matrix starts with

Category I in which manufacturing activities are identified.

From here dots are placed in the squares corresponding to those

potential environmental alterations (Category II) that are ex-

pected to occur for each of the activities. Also a dot is placed

in each box corresponding to the general level of potential for

TABLE 15· Items in the Manufacturing and Related Activities Category

_____

A) Construction

    1) Site Preparation and Building Facilities   ·Clearing
       (including connecting infrastructures,
       transmission facilities, etc.)
    2)   ·Filling
    3)   ·Dredging
    4)   ·Paving
    5)   ·Excavation
    6)   ·Erecting Facilities
    7)   ·Erecting Supporting Structures
    8)   ·Transportation Equipment
        and Materials
    9)   ·Labor Force Commuting

B) Facilities and Structures

    10) Production Related Facilities   ·Contigous Property (fenced
         or Unfenced)
    11)   ·Plant and Stacks, Towers
    12)   ·Warehouse
    13)   ·Offices
    14)   ·Lighting Systems
    15)   ·Parking Lots and Loading
         Terminals
    16)   ·Open Storage Areas

C) Production Activities and By-Products

    17) Production Residuals   ·Biodegradable
    18) (Liquid)   ·Non-biodegradable
    19) (Gaseous)   ·Particulates
    20)   ·Non-visible Gases
    21) (Solid)   ·Biodegradable
    22)   ·Non-biodegradable
    23) (Sound)   ·Manufacturing
    24) Associated Manufacturing Activities   ·Work Force Commuting
    25)   ·Produce and Raw Materials
        Shipping
    26)   ·Surface Water Intake and
        Discharge
    27)   Ground Water Intake and
        Discharge
    28)   Cooling Water Discharge

29) Infrastructure (increased demand for and expansion of the community infrastructure and service due to increased population and manufacturing use) •Roads

30)   Rail
31)   •Water Transport
32)   •Air Transport
33)   .Sewers and Sewage Treatment
34)   •Electric Power
35)   Utility Transmission
36)   •Schools
37)   Health Facilities Service
38)   •Housing
39) (Tourist Facilities bars, night clubs, bowling alleys, tennis courts, theaters •Recreation Facilities
40) (Churches, museums, libraries, etc.)   •Cultural Services
41)   •Safety Services
42) (Newspaper, radio, T.V.)   •Media
43) Population   •Migration
44)   •Spatial Distribution

TABIL 16.   Items in the Potential Environmental Alterations Category

Aesthetics
    1) Artificial Coloration
    2) Odor
    3) Alteration of Visual Composition/Profile

Land
    4) Loss of Open Space
    5) Loss of Dunes
    7) Loss of Forest and Vegetation
    /) Loss of Littorial Shallow Areas
    8) Loss of Marsh
    9) Increase in Erosion
    10) Increase in Frequency, Intensity, and Duration of Man-Made Noise
    11) Increase in Accumulation of Glass, Metals, Plastics, Cement, Asphalt

Air
    12) Increase in Hazardous/Toxic Substances
    13) Increase in Nitrogen Oxide
    14) Increase in Non-Methane Hydrocarbons
    15) Increase in Carbon Monoxide
    16) Increase in Sulfur Dioxide
    17) Increase in Particulate Matter
    18) Increase in Dust

Water
    19) Increase in Phosphates and Nitrates
    20) Increase in Fecal Coliform
    21) Change in Frequency or Volume of Surface Flow
    22) Groundwater Balance
    23) Increase in Suspended Solids and Turbidity
    24) Change in Ambient Temperature
    25) Change in Salinity
    26) Change in pH
    27) Increase in Hazardous/Toxic and Radioactive Substances
    28) Decrease in DO
    29) Increase in Gross Solids
    30) Increase in Dissolved Solids
    31) Increase in Oil Accumulation

Community
    32)
    33) Change in Per Capita Income Level
    34) Change in Marital Category Distribution
    35) Change in Sex Ratio

36) Change in Family Size
37) Change in Age Distribution
38) Change in Educational Level
39) Change in Ethnic or Racial Composition
40) Change in Population/Acre

TABLE 17   Items in the Major Environmental Effects Category

A. Ecology

1) Loss of Stability in Aquatic Systems
2)   •Killing of Aquatic Organisms (Reducing Populations)
3)   •Organic Accumulation of Lethan or Sub-Lethal Substances
4)   •Alteration of Areal Base of Aquatic Food Chains
5)   •Alteration of Composition and Abundance of Aquatic Micro Flora and Fauna
6)   •Elimination of Species
7) Loss of Stability in Terrestrial Ecosystems
8)   •Alteration of Areal Base of Terrestrial Food Chains
9)   •Killing of Terrestrial Organisms (Reducing Populations)
10)   •Decrease of Shelter and Forage for Terrestrial Fauna
11)   •Elimination of Species

B. Aesthetic

12)   •Structural Corrosion and Deterioration
13)   •Alteration of Urban Rural Composition
14) (Man-Made Structures)   •Alteration of Community Structural Composition
15)   •Loss of Integrity of Historical/Cultural Areas
16)   •Loss of Unique Natural Composition
17) (Natural)   •Creation of Odor
18)   •Decrease in Water Clarity
19)   •Decrease in Air Clarity

C. Physical/Biological

20)   •Alteration of Chemical Composition of Air
21)   •Alteration of Chemical Bacteriological Characteristics of Water (Salinity, etc.)
22)   •Increase in Radioactivity
23)   •Alteration of Natural Sound Patterns

D. Social/Human Environment

24)   •Disruption of Established Activity Patterns
25)   •Loss of Community Cohesion/Traditions Social Interaction Patterns
26)   •Introduction of Alien Value Systems
27)   Alteration of Traditional Visible Economic Patterns
28)   •Alteration of Work Routines/Patterns
29)   Alteration of Political Participation and Existing Power Structure
30)   Alteration of Established Land Use Patterns
31)   Increase in Congestion

172

TABLE 18   Items in the Human Uses Affected Category

1)   Deterioration in Biological Human Health
2)   Unrestricted Natural/Open Areas
3)   •Quietude
4)   •Diversity
5)   •Non-Offensive Surroundings
6)   Deterioration in Real or Perceived Well Being (Psychological)
7)   Developing Understanding of Natural Systems
8)   Visitation to Natural/Scenic Areas
9)   •Recreational Driving
10)   Photography/Painting
11)   •Hiking/Bicycling
12)   •Sport Fishing
13)   •Hunting
14)   •Clamming/Crabbing
15)   Deterioration in Extensive Recreation Uses and Visual Access
16)   •Swimming
17)   •Boating
18)   •Picknicking
19)   Photography/Painting
20)   Camping
21)   •Visitation To and Perception Of Historical/Cultural Areas
22)   •Beach/Waterfront Park Activities
23)   Deterioration in Intensive Recreational Uses
24)   Water Supply
25)   Commercial Fishing
26)   •Farming
27)   •Recreational Homes
28)   Deterioration in Other Uses (Including Commercial, Industrial,
        Residential)

impact in each of the three subregions of the Coastal Zone
Category V). Working from the dot in the interaction of
categories I and categories II, the reviewer should match the
columns in Category II (Potential Environmental Alteration)
with the dots placed in Category III (Major Environmental Effects)
The relationship then proceeds to category IV in which all boxes
indicating interaction of major environmental effects (Category
III) are matched with Category IV (Human Uses Affected). In
Category IV the relationship of effects on human utilization in
terms of magnitude of impact in the three subregions is
evaluated in the last section of the matrix (Category VI).

7. For all interactions between categories I and II, the symbols
    p,t, or o appear as superscripts to the dots. These represent
    temporary (t), operationally dependent (o) and permanent or
    long lasting (p) environmental alterations associated with
    each of the manufacturing activities.

8. It should also be pointed out that evaluations of the magnitude
    of potential damage (Category V) and magnitude of degradation
    of human uses (Category VI) in each subregion are based on
    estimates of resource importance. In Subregion One of the
    Delaware Coastal Zone, the potential for environmental damage
    is based to a large extent on the population concentrations
    and environmental scarcities of air and water quality that
    exist in that area. For Subregion Two the importance of main-
    taining the integrity of the marshlands and the wildlife
    refuges is the primary criteria for evaluating impact. In

In Subregion Three, conflict with recreational and tourists activities is the major consideration in determining the importance of impact.

9. Activities (I). In this category, a general list of activities associated with the construction and operation of manufacturing facilities is presented. This is broken down into the construction phase, the physical presence of facilities and structures, and production activities and by-products, under the heading production activities and by-products is included the activities associated with induced growth that may occur in communities adjacent to new manufacturing activities or in communities affected in terms of employment These induced activities are described primarily in terms of construction and operation of new roads and other forms of public infrastructure and community support services. In terms of Figure 2, this cateogyr encompasses 1, 6, and part of 4.

The purpose of Cateogry I is to depict both the first round activities associated with manufacturing and those activities which are indirectly related to new manufacturing location. Combining community growth with manufacturing location is an attempt to capture the dynamic aspect associated with location of new manufacturing activities or expansion of existing facilities It does not presume that the additions to community infrastructure or public facilities occur necessarily at the same time that the manufacture facilities locate but rather that over time the addition of the population associated

-44-

with manufacturing activity will create the necessity of expansion of public facilities. Expansion of these facilities are a definite contributing factor to environmental deterioration and therefore an essential part of the activities associated with manufacturing location. Inclusion of both the first round and second round activities does not imply that the second round activities have equal importance in terms of environmental impact with first round activities. Their inclusion is only suggestive of the fact that manufacturing activity will eventually lead to such changes and that these changes will have environmental impacts.

10. Potential Environmental Alterations (II). The activities associated with manufacturing location will lead to certain changes in the environment. These changes are of a physical/ biochemical or structural nature or in some cases demographic. The alterations in themselves are not the environmental effect, but rather the change in environmental parameters which ultimately produce environmental effects.

Community changes are also included in this cateogry. These changes relate specifically to demographic variables and population concentrations. The difficulty underlying the inclusion of these parameters in this category of the impact matrix is that location of new facilities creates influx or can create influx of new people causing alterations in traditional or past demographic characteristics. It is realized that the increases and expansion of infrastructure and the change in

-45-

community demographic variables are simultaneous and inter-related occurrences. The impact matrix, however, artificially separates these two for purposes of analysis in terms of impact on the biological, physical and human environment of the coastal zone. In terms of Figure 2, this cateogry encompasses boxes 2, and part of 3, 4 and 7.

11. Major Environmental Effects (III). This category provides a breakdown of changes and environmental systems and environmental conditions directly related to the potential environmental alterations listed in Category II. Major environmental effects in this category will include impact on ecology, aesthetic qualities, physical/biochemical aspects of the environment, and descriptors of social/human environment. In terms of Figure 2, this category encompasses boxes 5, and parts of 3 and 7.

12. Human Uses Affected (IV). Items in this category relate specifically to the human utilities or satisfaction derived from utilization of the coastal environment for residential, recreational, and other economic activities This listing represents those activities which may be adversely affected by poorly planned manufacturing use of the Coastal Zone. In terms of Figure 2 this category encompasses box 8.

-46-

IV. Sorensen Environmental Impact Network (9)

   A. Basic Principles

      1. The basic approach is an attempt to understand the impact
         of any proposed use on the total resources system. This is
         accomplished through the use of a cause-condition-effect matrix.

      2. Figure 4 shows how a network is formed by linkages between
         causes-conditions-effects.

      3. The basic principles of the Sorensen approach is to use
         matrices arranged to identify where potential relationships
         exist between:

         (a) causes and conditions (Table 19)

         (b) conditions and conditions (Table 20)

         (c) conditions and effects. (Table 21)

      4. A "stepped matrix" approach is utilized.

   B. Matrix-Network Components

      1. Figure 5 illustrates the basic components in the method

         (a) Uses of the coastal zone are identified.

         (b) Causal factors are alterations commonly associated with
             a use that directly produces a change in condition.

         (c) Initial conditions are defined here as the initial
             identifiable impacts of the causal factors. They
             indicate what change has been known to occur before and
             could likely reoccur as the consequence of a causal
             factor. The dot linkage between causal factors and
             initial condition does not indicate that there is an
             invariable connection between the two. It indicates a
             potential relationship.

-47-

Figure 4   A Network Analysis of Dredging
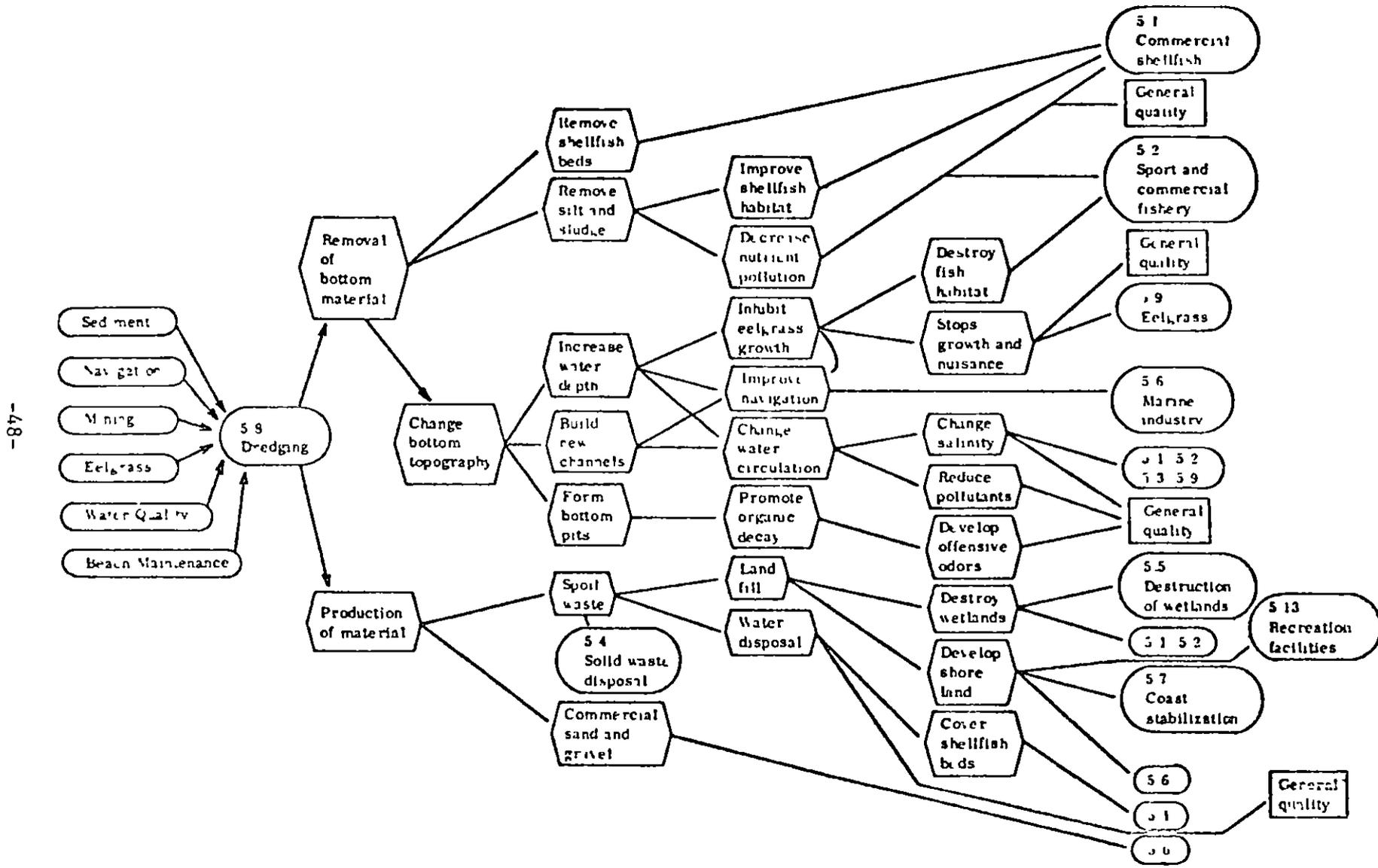
FIGURE 5: RESIDENTIAL, COMMERCIAL, AGRICULTURAL
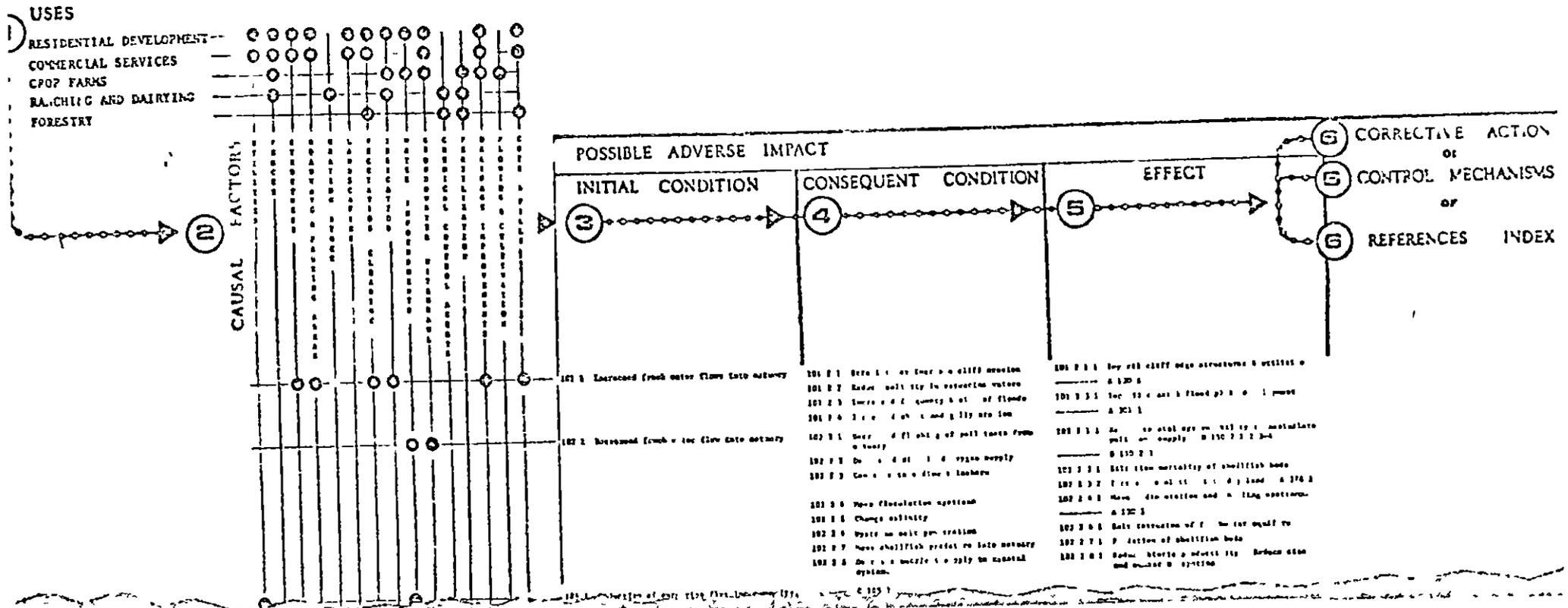
CAUSAL FACTORS	ENVIRONMENTAL CONDITIONS AFFECTED
Air circulation	
Moisture amount and distribution	
Solar radiation	
Water circulation	
Erosion	
Sedimentation	
Crop production	
Livestock production	
Pesticide and fertilizer application	
Finfishing	
Shellfishing	
Aquaculture	
Navigation improvements	
Coast facility improvements	
Food processing	
Oil refining	
Metals and related fabrication	
Sand and gravel mining	
Other mineral extraction	
Drinking and other personal uses	
Municipal uses	
Irrigation	
Manufacturing and processing	
Road building	
Utility construction	
Land filling and draining	
Domestic disposal	
Industrial disposal	
Agricultural waste disposal	
Cooling pond disposal	
Boating	
Swimming and other water contact activities	
Fishing	
Passive recreational activities	
Pest control spraying	

-50-

TABLE 20: Interaction Among Environmental Conditions

ENVIRONMENTAL CONDITION AFFECTED

CHANGED ENVIRONMENTAL CONDITION

HUMAN ACTIVITY AFFECTED

Column headers (read vertically):
Crop production · Livestock production · Pesticide and fertilizer application · Fishing · Shellfishing · Mariculture · Navigation improvements · Coast facility improvements · Food processing · Oil refining · Metals and related fabrication · Sand and gravel mining · Other mineral extraction · Drinking and other personal uses · Municipal uses · Irrigation · Manufacturing and processing · Road building · Utility construction · Land filling and draining · Domestic disposal · Industrial disposal · Agricultural waste disposal · Dredging spoil disposal · Boating · Swimming and other water use facilities · Fishing · Hunting · Facility restoration activities · Facility abandonment

CHANGED ENVIRONMENTAL CONDITION

ONSHORE
Changed Environmental Condition	Code
Surface elevation change	1 2 1 1 1
Surface area change	1 2 1,1,2
Surface slope change	1 2 1 1 3
Surface hydrology change	1 2 1 1 4
Subsurface geology change	1 2 1 1 5
Subsurface hydrology change	1 2 1 1 6
Surface cluttering – surface materials	1 2 1 1 7
Surface chemical composition change	1 2 1 . 1
Subsurface chemical composition change	1 2 1 -
Surface biological organism change	1 2 1 1 1
Subsurface biological organism change	1 2 1 1 2

OFFSHORE
Changed Environmental Condition	Code
Floor bottom topography change	1 2 2 1 1
Channel depth and/or width change	1 2 2 1 1
Shoaling (natural)	1 2 2 1 1 1
Pitting	1 2 2 1 1 -
Change in depth	1 2 2 1 1
Floor bottom shape change	1 2 2 1 1 6
Floor bottom material composition change	1 2 2 1 1 7
Change in chemicals on floor	1 2 2 1 2 1
Change in chemicals under floor	1 2 2 1
Change in biological organisms on floor	1 2 2 1 2 1
Solid material content change	1 2 2 2 1 1
Settleable, floating and suspended solids	1 2 2 2 1 1
Water temperature change	1 2 2 2 1 1
Surface water chemical changes	1 2 2 2 2 1
Subsurface water chemical changes	1 2 2 2 1
Surface water biological changes	1 2 2 2 1
Subsurface water biological changes	1 2 2 2 3 1

AIR
Changed Environmental Condition	Code
Surface area change	1 2 3 1 1
Surface chemical composition change	1 2 3 2 1
Subsurface chemical composition change	1 2 3 2 2
Floor pit composition change	1 2 3 1 1
Air particulate content change	1 2 4 1 1
Air clarity change	1 2 4 1 2
Airborne chemical agent content change	1 2 4 1 1
Changes in visual appearance	
Changes in noise level	
Generation of obnoxious odors	
Change in level of radioactivity	

(d) Consequent conditions describe the changes induced by the

initial condition that ultimately produce the effect or

effects. In this stage of the framework consequent con-

ditions are confined to one column, althrough several

columns could have been used to fully describe the chain

of development between some initial conditions and ultimate

effects (e.g., physical barrier to alongshore beach and

water access -- concentration of public use within a

limited area -- trampling of beach and shoreline

vegetation -- mortality or stunting of shoreline vegetation

cover -- dune blowouts or migration, wind erosion).

(e) The effects are the listing of the actual use conflicts

(i.e., impair skin diving and underwater exploration) or

resource change that would contribute to a use conflict

(i e., aesthetic displeasure will reduce recreational

and residential appeal). In most cases the conditions

listed in the effects column are not stated in terms of

direct conflicts with another use or uses. Conflict

could be described in an additional listing, adjoining

the effects column However, this addition may not be

necessary because the effect statements as they stand

now are usually specitic enough to indicate both the manner

and direction of the consequence upon uses

(f) Corrective actions are the physical measures commonly

employed to reduce or eliminate the adverse ettects of the

preceding column. The listing could also indicate untried

techniques or innovative technology. Many corrective

actions are causal factors to further networks of adverse

conditions and effects. Dredging is the normal corrective

action for sedimentated ship channels. Dredging,

however, is also the causal factor in filling of wetlands

with spoils.

(g) Control mechanisms are methods other than direct physical

action that might be instituted to regulate, reduce, or

eliminate the indicated adverse effects. Examples would

be permits, codes, plan review, zoning, easements, and

legislation.

2. Fifty-five uses are identified in the Sorensen method, and they

are listed in Table 22.

3. Causal factors used in the method are listed in Table 23, and

are identified based on the assumption that they are presently

being generated by the use in question. The matrix matching

of causal factor to use is intended to mean there presently is

a more than frequent relationship between the two.

4. The initial conditions listing is organized vertically into

six groupings, representing changes in. water, climate,

geophysical conditions, biota, access conditions, and

aesthetics.

TABLE 22: Coastal Zone Uses

Category	Uses
Residential, Commercial, Agricultural	Residential Development Commercial Services Crop Farms Ranching and Dairying Forestry
Recreational	Motorboating Boat Fishing Water Skiing Sailing Surf Fishing Pier Fishing Swimming Scuba-Snorkling Wading Sunbathing Group Beach Games Beachcombing - Strolling Clamming - Bait Collecting Picnicking - Cook Outs Contemplation - Observation Painting - Photography Wildlife Observation Hunting Horseback Riding Beach and Dune Driving Shopping - Boardwalking Ocean-view Dining Sightseeing - Pleasure Driving Camping
Extractive	Commercial Shrimp and Finfishing Commercial Shellfishing Abalone Fishing Kelp and Seaweed Harvesting Shore Oil and Gas Wells Offshore Oil and Gas Wells Shore Mining and Quarrying Sand, Gravel, and Shell Mining Desalinization Seawater Chemicals Extraction

Category	Uses
Industrial, Transportation	Marine Transport
	Highway Transport
	Air Transport
	Rail Transport
	Communications
	Navy Operations
	Military Facilities
	Marine Research
	Industrial Operations
	Power Plants
	Sewage Treatment Plants

TABLE 23: Causal Factors in the Coastal Zone

Category	Causal Factor
Residential, Commercial, Agricultural	Septic Tanks
	Sewer System
	Solid Wastes
	Groins and Beachworks
	Signs and Billboards
	Vehicles
	Utilities
	Fences
	Structures
	Roadways and Parking Areas
	Grazing Stock
	Landscaping
	Vegetation Clearing and Logging
	Irrigation
	Water Impoundments
	Grounwater Withdrawal
	Chemical Control Agents
	Fertilization
	Drainage Improvements
	Plowing and Cultivation
	Cuts and Fills
Recreational	Protection of Species
	Collection of Species
	Landscaping
	Utilities
	Sewage and Trash Disposal
	Picnic Facilities
	Signs and Billboards
	Fences
	Toilet Facilities
	Structures
	Vehicles
	Paths to Shore
	Vehicle Trails
	Launching Ramps
	Roads to Shore
	Turnouts and Vista Points
	Roadways and Parking Areas
	Channels
	Breakwater
	Groins and Beachworks
	Navigation Aids
	Docks and Piers

Category	Causal Factor
	Fuel Docks
	Slips and Berths
	Boatyards
	Boats
Extractive	Stock Introductions
	Collection of Species
	Prospecting
	Temporary Housing
	Processing Plants
	Refineries and Tank Farms
	Towers and Platforms
	Offshore Drilling
	Excavation
	Dredging
	Gangue Dumping
	Offshore Beneficiation
	Wastewater
	Seawater Intakes
	Pipelines
	Submerged Fencing
	Evaporation Beds
	Slips and Berths
	Channels
	Breakwaters and Jetties
	Fuel Docks
	Docks and Piers
	Boatyards
	Boats and Barges
Industrial, Transportational	Collection of Species
	Practice Ranges
	Defense Operations
	Power Pylons and Wires
	Transmission Towers and Antennae
	Utilities
	Fences
	Runways
	Aircraft
	Vehicles
	Railroads
	Roadways and Parking Areas
	Building Site Cuts and Fills
	Roadbed Cuts
	Bridges
	Roadbed Fills and Causeways

Category	Causal Factor
	Water Impoundments
	Solid Waste
	Wastewater and Sewage
	Nuclear Reaction
	Fossil Fuel Combustion
	Bulk Refining and Processing
	Tanks Elevators and Warehouses
	Structures
	Bulk and Fuel Loading
	Navigation Aids
	Slips and Berths
	Channels
	Breakwaters and Jetties
	Docks and Piers
	Shipyards
	Nuclear Ships
	Ships

V. Example of "Sorensen-Type" Matrix (10)

    A. Project

        1. The project was for renewal and development of a 74-acre

            industrial park (Fruit/Church Industrial Park) in the south-

            western portion of Fresno, California.

        2. The project, financed by the Economic Development Administration,

            involved two separate and simultaneous actions. The first action

            was a loan to improve the processing facilities of two industries

            currently located within the project site. This loan permitted

            increased production and control of the emission of objectionable

            odors. The second action was a grant to the City of Fresno.

            It permitted the acquisition, renewal and development of the 74

            acre site into improved sites for use by heavy industry.

    B. Explanation Environmental Impact Matrix

        Figure 6 is a guide to the use of the impact matrix, which should

        be interpreted in ten steps:

        1. Enter the Matrix at the upper left hand corner under the

            heading Project Elements. In the example - 2. Future

            Improvements.

        2. Read to the right. A possible causal factor which may cause

            an impact is shown at Surfacing.

        3. A dot   ⬤   indicates that a relationship exists between

            2. Future Improvements and Surfacing.

        4. Read downward from the   ⬤   until either a ☆ , ☆ ,

            ▢ , ◻ , or ∪ is encountered.

            If a ☆ appears, a major positive impact exists

-60-

CAUSAL FACTORS

PROJECT ELEMENTS

SURFACING

2. FUTURE

ALTERED ELEMENTS

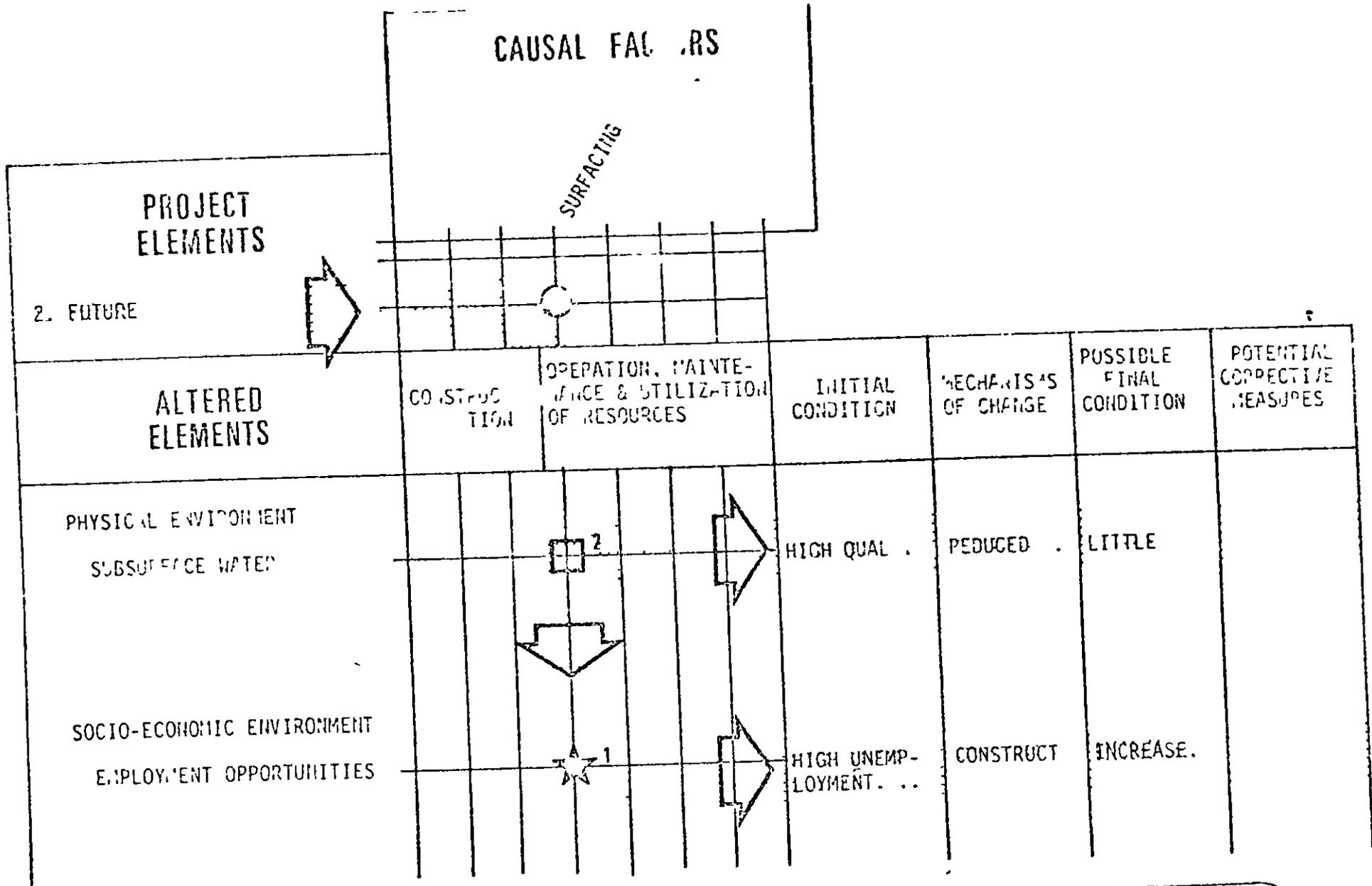|	CONSTRUCTION	OPERATION, MAINTENANCE & UTILIZATION OF RESOURCES	INITIAL CONDITION	MECHANISMS OF CHANGE	POSSIBLE FINAL CONDITION	POTENTIAL CORRECTIVE MEASURES
PHYSICAL ENVIRONMENT SUBSURFACE WATER		[2]	HIGH QUAL .	REDUCED .	LITTLE	
SOCIO-ECONOMIC ENVIRONMENT EMPLOYMENT OPPORTUNITIES		[1]	HIGH UNEMPLOYMENT. ..	CONSTRUCT	INCREASE.	

Figure 3   QUANTITATIVE IMPACT MATRIX

-91-

A ✦ indicates a minor positive impact exists

A ▭ indicates a major negative impact exists

A ◻ indicates a minor negative impacts exists

A ∪ indicates an impact exists, but its magnitude

or direction cannot be determined at present.

Reading downward from Surfacing, a ◻ is shown.

5. Read to the left. A minor negative impact will change Sub-
surface Water. The 2 next to the ◻ indicates that the
impact originates at 2. Future Improvements.

6. Read to the right

7. Under the column headed INITIAL CONDITION the notation reads
High Quality indicating that the altered element is presently
of high quality.

8. Under the column headed MECHANISM OF CHANGE will be a
notation describing the mechanism which will change that
altered element

9. Under the column headed POSSIBLE FINAL CONDITION will be a
notation describing the condition of the altered element after
the impact has taken place.

10. The POTENTIAL CORRECTIVE MEASURES column is reserved for those impacts against which some steps have been or could be taken to minimize the impact.

C. Use of Matrix

1. Figure 7 shows the completed matrix.

2. Glossary of terms used is as follows:

Clearing - the removal of trash, structures and other material now occupying the project site. This includes the removal of vegetation and all deletrious materials.

Utilities - refers to the trenching, installation, recovering and all construction necessary for the installation of sewer, water, gas, electric and telephone equipment.

Grading - any cut or fill operations necessary to prepare the site for future development.

Surfacing - placement of any impervious material on the ground surface.

Street Widening and New Streets - all construction necessary to improve existing streets or place new streets within or adjacent to the project site as planned. Includes the acquisition and preparation of land necessary to upgrade existing streets.
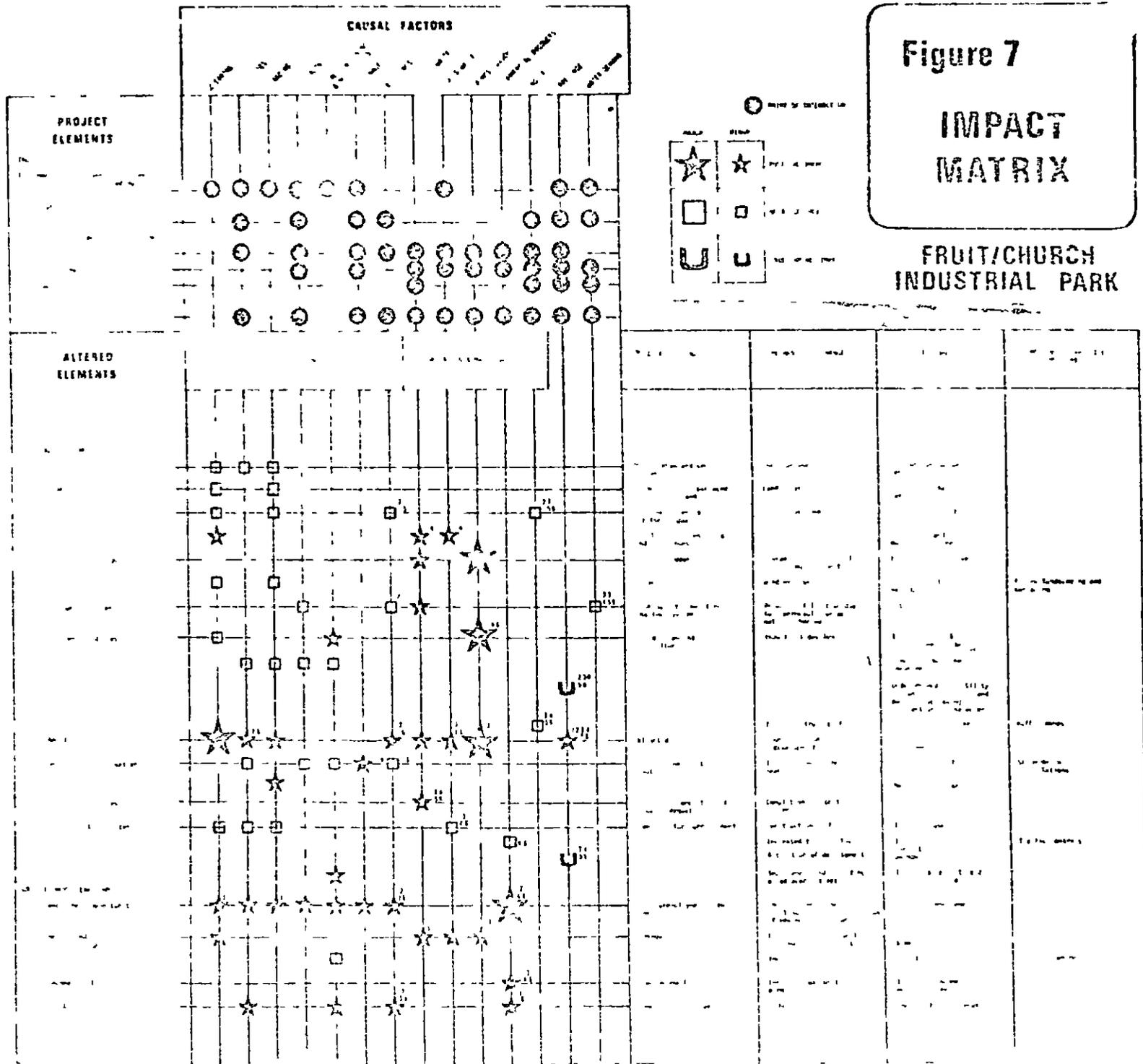
Drainage - is the containment and routing of storm water runoff to a safe place of disposal.

Buildings - includes all renovations to the existing structures within the project site and construction activities to place new structures within the project site.

Figure 7

IMPACT MATRIX

FRUIT/CHURCH INDUSTRIAL PARK

Liquid Waste - all liquid resulting from domestic manufacturing or processing activities currently taking place within the project or future industries which is not intended for further use or sale.

Solid Waste - any non-liquid material resulting from manufacturing or processing which is not intended for reuse or sale including combustible trash

Atmospheric Discharges - any discharge of gaseous or particulate matter into the atmosphere

Commercial Products - any materials resulting from manufacturing or processing activities which are intended for use or sale.

Noise - the noise level within and adjacent to the project site and including all causes thereof

Presence - the non-quantifiable quality of the site which may result in any impact or change resulting from the mere fact of being there, apart from its esthetic or physical properties.

Water Demand - the quantity of water required for human or industrial consumption within the site

Soils - in the agricultural sense referring to its capability for supporting vegetation and not including its mechanical or engineering properties.

Surface Drainage - the movement of surface water by gravity.

Subsurface Water - water occupying the saturation zone from which wells are fed.

Air Quality & Climate - the quality of air in terms of the currently used air pollution index, including detectable odors.

Climate includes all recordable meteorlogical phenomena
including temperature, precipitation, wind speed and direction
and relative humidity.

Vegetation - any naturally occurring or man-placed plant
material within the project area.

Animal Life - any life form occurring within or affecting the
project area.

Amenity - the perceived pleasantness of any part of or the pro-
ject as a whole or its surroundings which may be affected by
the project.

Adjacent Land Uses - all zone-conforming or nonconforming
land uses within the project area which may be affected by the
project.

Transportation - all facilities necessary to mechanically
move goods and people

Employment Opportunities - the opportunity for increased levels
of employment or greater variety of employment.

Income Level - the average purchasing power of families within
the area affected by the project.

Tax Base - the combined assessed value of personal and real
property upon which taxes are based.

Utility Facilities - specifically the following. sewer, water,
gas, electricity and telephone.

Health and Safety - the general level of health of persons
occupying areas affected by the project and the protection of
those persons from exposure to hazard.

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Checklists for Impact Assessment

by

L.W. Canter*

Checklists represent one of the basic methodologies developed for use
in environmental impact assessment. This discussion is oriented to a pre-
sentation of several examples four each of four broad categories of checklists.

I. Introduction

    A. Definition: Checklist methodologies present a specific list of envi-
ronmental parameters to be investigated for possible impacts but do
not require the establishment of direct cause-effect links to project
activities. They may or may not include guidelines on how parameter
data are to be measured and interpreted. They may have developed
parameter weighting systems. (1)

    B. Categories of Checklists

        1. Simple checklists: a list of parameters is indicated, however,
no guidelines are provided on how parameter data are to be mea-
sured and interpreted.

        2. Descriptive checklists a list of parameters is indicated, and
guidelines are provided on how parameter data are to be measured.

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3   Scaling checklists   same as descriptive checklists with infor-

mation provided as to subjective scaling of parameter values.

4.   Scaling-weighting checklists·   same as scaling checklists with

information provided as to subjective weighting of parameter

with respect to each other

II.   Examples of Simple Checklists

A.   Corps of Engineers (2)

1.   Relationship of the Proposed Action to Land Use Plans. Discuss

how the proposed project or action conforms or conflicts with

the objectives and specific terms of existing or proposed Fed-

eral, State, and local land use plans, policies and controls,

if any, for the area affected. If a conflict should occur,

the statement should discuss the issues completely and state

the actions that the Corps has taken to reconcile its proposed

action with the plan, policy or control, and the reasons for

proceeding with the project notwithstanding the absence of full

reconciliation.

2   The Probable Impact of the Proposed Action on the Environment

a.   Impacts on the environment including water, land and air,

would be viewed as changes or conversions of environmental

elements which result directly or indirectly from the pro-

posed action   These impacts and effects should initially

be identified and projected throughout the life of the pro-

ject.   Include land loss and land use changes which could be

expected upstream, downstream, and adjacent to the project

such as urbanization changes in water features and character-istics, air quality, aesthetics, etc. Discuss the impacts on the environment of project-induced primary and secondary economic and social effects, including cumulative effects.

Such impacts shall be detailed in a dispassionate manner to provide a basis for a meaningful discussion of the trade-offs involved in the SOF. Quantitative estimates of losses or gains (e.g., acres of marshland, miles of white-water streams inundated, etc.) will be set forth whenever practicable. Where this cannot be done, qualitative descriptions of unquantifiable environmental costs and benefits should be provided with assumptions or criteria on which judgments are based. Data developed from the effect assessment for environmental effects (Section 122) should be used as input for the "with project condition."

b. The description of the proposed action should include a summary of the population projections employed as a basis for formulation and evaluation. The sources of the population data, whether OBERS or another origin, should be identified. Other projections, such as future economic activity and land use, that also bear upon a thorough understanding of the environmental impacts of the proposed action should be included along with their source. When preparing the environmental statement, care should be taken to only include information that is necessary to fully understand the proposed action and its attendant environmental impacts. In

order to keep the statement brief, the environmental statement should contain references to more detailed information in the appropriate sections of the decision document. Discuss both the beneficial and adverse impacts of the environmental changes or conversions placing some relative value on the impacts described Discuss these effects not only with the reference to the project area, but in relation to any applicable region, basin, watershed, or ecosystem. Relate the impact to the river basin or regional entity in which the action is proposed, and discuss the inter-relationship of projects and alternatives proposed, under construction or in operation by other agencies or organizations. A thoughtful assessment of the environmental elements should aid in determining impacts. For example, the filing of a portion of the wetlands or an estuary would involve the obvious conversion of aquatic/marsh areas to terrestrial environments, the loss of wetland habitats and associated organisms, a gain in area for terrestrial organisms, a change in the nutrient composition of the runoff water entering that portion of the estuary, alteration of the hydrology of some given area, perhaps the introduction of buildings or roads, curtailment of certain commercial uses, disruption of water-based recreational pursuits, conversion of wildlife aesthetics to less-pristine attributes, perhaps the removal of same portion of popular duck hunting grounds or unique bird nesting area, etc

c. Identify remedial, protective, and mitigation measures which would be taken as a part of the proposed action by the Corps or others, to eliminate, or compensate for, any adverse aspects of the proposed action. Such measures taken for the minor or short-lived negative aspects cannot be satisfactorily dealt with will be considered in greater detail along with their abatement and mitigation measures in subparagraph e.

d. For O&M maintenance dredging projects which are segments of a total sytems, i.e., the intracoastal waterway, and for which it has been determined that separate rather than a composite environmental statement be prepared, the need to discuss the inter-relationship of the segments with the total project including cumulative environmental impacts over the life of project is mandatory. Points to consider in preparing the statement should include; periodicity of dredging requirements, volume of material removed to date and projected in the future, dredging methods used in past and project for future uses, location and expected life of authorized spoil disposal areas, projected needs and plans for establishing new areas, experienced rate and type of revegetation and changes in wildlife values on completed and existing disposed areas, quality of dredge spoil throughout the project area with particular coverage of any areas where chronic pollution exists and how such spoil has been and will be handled, and a general description of fauna and flora within the project area including a thorough analysis of how proposed dredging operations will affect these organisms

3. <u>Alternatives to the Proposed Action</u>. Describe the various rea-
sonable structural and non-structural alternatives to the proposed
action, their environmental impact, their ability to accomplish
the objectives, either in whole or part, of the proposed action,
specifically taking into account the alternative of no action.
The "effect analysis" as required by Section 122 for survey and
continuing authority reports and Phase I GDM's will provide
necessary information to the planner in developing the full range
of effects of project alternatives to eliminate, reduce, or mini-
mize adverse environmental effects or to enhance environmental
qualities. For each viable alternative considered, particular
economic, social, and environmental effects of the planned action
must be assessed and weighed against other alternatives in the SOF
A thorough discussion of this balancing analysis in the SOF will
provide evidence that the decision making process has in fact
taken place, that it will allow others to evaluate and balance
the factors on their own, and that the final project recommenda-
tion is made in the best overall public interest.

In discussing the various alternatives to accomplish the ob-
jectives of the proposed action, three general categories should
be followed   (1) Describe those alternatives which would accom-
plish all of the objectives of the proposed action, (2) describe
those alternatives which may only provide a partial solution to
all or part of the objectives of the project, as one example
including land acquisition or other land use controls in the
flood plain in the case of flood control projects, and

-6-

(3) describe the no development alternative. Rules of reason-
ableness must also be followed in deciding what alternatives
are proper subjects for discussion. These are summarized as
follows

a. The fact that an alternative action cannot be implemented
   by the Corps does not by itself make the alternative not
   reasonably available. If alternatives requiring action
   by another agency or legislative action are not remote or
   speculative possibilities, they must be discussed in the
   statement. In discussing such alternatives, information con-
   tained in studies by other agencies, responsible journals
   and other agencies environmental impact statements may be
   used

b. Reasonably available alternative actions and responsible views
   in opposition to a proposed action which are contained in
   comments on the environmental impact statement submitted by
   interested citizens or citizens' groups must be discussed.

c. The range of alternatives that must be evaluated in an en-
   vironmental impact statement concerning a proposed action
   which is an integral part of a wide-spread coordinated plan
   must be broadened beyond those alternatives that would be
   considered in the case of a project of more limited scope,
   such as a local protection project

d In the case of a proposed action intended to respond to an
   immediate need, an alternative action that will provide on-
   ly a long-term solution is probably not a reasonably available
   alternative and does not have to be discussed.

-7-

19.

B. Little Method for DOT (3)

1. This method is basically oriented to a discussion of the impacts associated with a transportation project.

2. Table 1 spells out a range of potential environmental impacts of a transportation project by.

    a. category of impact

    b. likely significance of major impacts at the principal stages of the project, the project stages are:

        (1) planning and design

        (2) construction   •

        (3) operation

    c. x denotes impact, could be (+) or (-)

3   Table 2 has classification of impacts according to those occurring in'

    a. planning and design phase

    b. construction phase

    c. operation of facility - direct impacts

    d   operation of facility - indirect impacts

4   Table 3 has effects according to areal considerations

5. Procedural options for determining the perceived significance of the impact of a transporation project upon the environment.

    a. Reliance on the emergence of controversy.

    b. Evidence of governmental concern through the A-95 comment procedure

    c. A presumption that significance is implicitly related to a project's scale or cost

TABLE 1

POTENTIAL ENVIRONMENTAL IMPACTS OF A TRANSPORTATION PROJECT
(by category of impact and the significance of major ones
at various stages of the project)

Category	Potential significance[1] at Stage of		
	Planning and Design	Construction	Operation
1. Noise Impacts		x	x
a. Public Health			
b. Land Use			
2. Air Quality Impacts		x	x
a. Public Health			
b. Land Use			
2. Water Quality Impacts		x	x
a. Ground Water			
(1) Flow and water table alteration			
(2) Interaction with surface drainage			
b. Surface Water			
(1) Shoreline and bottom alteration			
(2) Effects of filling and dredging			
(3) Drainage and flood characteristics			
c. Quality aspects			
(1) Effect of effluent loadings			
(2) Implication of other actions such as			

-disturbance of benthic
 layers
-alteration of currents
-changes in flow regime
-saline intrusion in ground
 water

[1] "x" denotes an impact which could be positive as well as negative,
depending on circumstances

TABLE 1 (Cont'd)

Category	Planning and Design	Construction	Operation
(3) Land use			
(4) Public Health			
Soil Erosion Impacts		X	X
a Economic and Land use			
b Pollution and Siltation			
5 Ecologic Impacts		X	X
a Flora			
b Fauna (other than man)			
6 Economic Impacts	X	X	X
a. Land Use			
(1) In immediate are of project			
(2) In local jurisdiction served or traversed			
(3) In region			
b Tax Base	X	X	X
(1) loss through displacements			
(2) Gain through increased values			
c Employment			
(1) Access to existing opportunities			
(2) Creation of new jobs			
(3) Displacement from jobs			
d. Housing and Public Services			
(1) Demand for new services			
(2) Alteration in existing services			

TABLE I (Cont'd)

Category	Planning and Design	Construction	Operation
e. Income	x	x	x
Damage to economically valuable natural resources		x	x
Socio-Political Impacts			
a. Damage to, or use, of,		x	x
(1) Cultural resources			
(2) Scientific resources			
(3) historic resources			
(4) Recreation areas			
b. Life style and activities	x	x	x
(1) Increased mobility			
(2) Disruption of community			
c. Perception of cost/benefit by different cohesive groups	x	x	x
(1) Racial			
(2) Ethnic			
(3) Income class			
d. Personal safety		x	x
Aesthetic and Visual Impacts		x	x
a. Scenic resources			
b. Urban design			
c. Noise			
d. Air Quality			
e. Water Quality			

TABLE 2

POTENTIAL ENVIRONMENTAL IMPACTS OF A TRANSPORTATION FACILITY
(by Phase of Project Development)

Lanring and Design Phase

    Impact on land use through speculation in anticipation of development
2   Impact of uncertainty on economic and social attributes of nearby areas.
3   Impact on other planning and provision of public services.
4   Acquisition and condemnation of property for project, with subsequent
    dislocation of families and businesses.

Construction Phase

1   Di placement of people
2   Noise
3   Soil Frosion and Disturbance of natural drainage.
4   Interference with water table.
5   Water pollution
6   Air pollution (including dust and dirt, and burning of debris).
7   Destruction of or damage to wildlife habitat
8. Destruction of parks, recreation areas, historic sites.
9   Aestnetic impact of construction activity and destruction of or inter-
    ference with senic values.
10 Impact of ancillary activities (e g , disposal of earth, acquisition
    of gravel and fill)
11 Commitment of resources to construction.
12 Safety hazards.

Operation of Facility -- Direct Impacts

1   Noise
2   Air pollution
3   Water pollution
4   Socio-economic
5   Aesthetic
6   Effects on animal and plant life (ecology).
7   Demand for energy resources

Operation of Facility -- Indirect Impacts

    Continuous land use
    Regional development patterns
3   Demand for housing and public facilities
    Impact on use of nearby environmental amenities (e.g. parks, woodlands,
    recreation area)
    Impact of additional and/or improved transportation into congested areas
    on those areas
6   Differential usefulness for different economic and ethnic groups (and
    resulting problems and solutions)
    Benefit in list of increased mobility and other impacts.
8   Impact of improved facility on transportation and related technological
    development (and consequent impacts)

TABLE 3

GEOGRAPHIC, LANDSCAPE AND URBAN FORM EFFECTS ON LAND USES
AND PATTERNS IN PROJECT OPERATIONS

a. Immediate area of project.

1. Displacement by project itself.

   (1) Residential
   (2) Commercial
   (3) Industrial
   (4) Public Facilities
   (5) Recreational
   (6) Natural Resources
   (7) Cultural resources.
   (8) Scenic resources
   (9) Wildlife resources.

b. Land-use choices affected by project.

   (1) Attracted by increased access·

       (i) Ancillary uses (facility or user service).
       (ii) Users benefiting from access (certain industrial, commercial,
            residential and public uses).

   (2) Disrupted by project

       (i) Incompatibility with noise, pollution, asethetic, safety
           and other effects of facility.
       (ii) Incompatibility with access-oriented uses
       (iii) Incompatibility resulting from increases access of non-
             resident users (e g , natural or wild areas).

c. Neighborhood (or area) services, facilities, and living patterns
   affected by facility

   (i) Disruption of service districts.

       (i) Public facilities.
       (ii) Private nonprofit services.
       (iii) Retail establishments

   (2) Effects on neighborhood cohesiveness and stability

d. Jurisdiction served or traversed by facility.

   a. Effect on land-use planning and controls
   b. Effect on planning and development of public facilities resulting from
      projects and land-use patterns generated or influenced by it (including
      effect on tax base, cost of services)
   c. Effect on areas not directly contiguous with project of actions by
      those displaced, disrupted, attracted, or otherwise affected by it.

TABLE 3 (Cont'd)

3. In region where project is located.

    a   Effect on regional development planning, inducement and controls.
    b. Revenue effects, influencing other public projects.
    c   Economic effects, influencing private development in the region as
        a whole and differentially within it.

d. Utilization of interdisciplinary approaches at the project

definition stage of planning to employ consensus techniques

in predicting the probability of significant impact intui-

tively, against a graded "significance scale". (See Table 4)

C. Federal Power Commission (4)

1. FPC has provided detailed guidelines from preparing environmental

reports, although not specifying units for parameter measurement

2. Sec. 3 of Appendix B applies to pipeline facilities as follows.

3. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION
Describe all know or expected significant environmental effects
and changes, both beneficial and adverse, which will take
place should the action be carried out. Include the impacts
caused by (a) construction, (b) operation, including main-
tenance, breakdown, and malfunctions, and (c) termination
of activities, including abandonment Include both direct
and primary indirect changes in the existing environment in
the immediate area and throughout the sphere of influence
of the proposed action 1/

3.1 CONSTRUCTION

3 1.1 Land Features and Uses -- Assess the impact on present or
future land use, including commerical use, mineral resources,
recreational areas, public health and safety, and the aesthe-
tic value of the land and its features. Describe any temp-
orary restriction on land use due to construction activities
State the effect of construction related activities upon lo-
cal traffic patterns, including roads, highways, ship channels,
and aviation patterns.

3 1.2 Species and Ecosystems -- Assess the impact of construction
on the terrestrial and aquatic species and habitats in the
area, including clearing, excavation, and impoundment Dis-
cuss the possibility of a major alteration to the ecosystem
and any potential loss of an endangered species

1/ Changes in the Environment Throughout the Sphere of Influence of Proposed
Action Direct and indirect effects are those effects which can be dis-
cerned as occurring primarily because the proposed action would occur For
example (1) the impact of a borrow pit would be evaluated to the extent
that it would be developed or expanded but the manufacture of conventional
trucks to work the pit would not, (2) the impact of construction workers
moving into the area would be evaluated but not the impact of their leaving
present homes However, the impact of their subsequent leaving this place
must be considered

-15-

TABLF 4

ENVIRONMENTAL IMPACT SIGNIFICANCE

	Significant Scale	
	Low	High
Impact	0 1 2 3 4 5 6 7 8 9 10	

Noise
Air Quality Deterioration
Water Quality Deterioration
People Displacement
Community Disruption
Aesthetic, Visual Impairment
Recreational Deterioration
Ecological Deterioration
Depletion of Natural Resources
Taking of Parkland, Historic Sites, etc.
Irreversibility
Controversy

3.1.3   Socio-Economic Considerations -- Discuss the effect on local
        socio-economic development in relation to labor, housing,
        local industry, and public services. Discuss the need for
        relocations of families and businesses. Describe the bene-
        ficial effects, both direct and indirect, of the action on
        the human environment, such as benefits resulting from the
        services and products, and other results of the action (in-
        clude tax benefits to local and state governments, growth
        in local tax base from new business and housing development
        and payrolls) Describe the impact on human elements, in-
        cluding the need for increased public services (schools,
        health facilities, police and fire protection, housing,
        waste disposal, markets, tranportation, communication,
        energy supplies, and recreational facilities)

3.1.4   Air and Water Fnvironment -- Estimate the qualitative and
        quantitative effects on air, noise, and water quality, in-
        cluding sedimentation, and whether regulatory standards in
        effect for the area will be complied with

3 1.5   Waste Disposal -- Discuss the impact of disposal of all waste
        material such as spoils, vegetation, construction materials,
        and hydrostatic test water.

3.2   OPERATION AND MAINTENANCE

3.2.1   Land Features and Uses -- Outline restrictions on existing
        and potential land use in the vicinity of the proposed action,
        including mineral and water resources. State the effect of
        operation related activities upon local traffic patterns in-
        cluding roads, highways, ship channels, and aviation patterns,
        and the possible need of new facilities \

3.2.2   Species and Ecosystems -- Assess the impact of operation upon
        terrestrial and aquatic species and habitats, including the
        importance on plant and animal species having economic or
        aesthetic value to man that would be affected by the action,
        provide pertinent information on animal migrations, foods,
        and reproduction in relation to the impacts, and describe
        any ecosystem imbalances that would be caused by the action
        and the possibility of major alteration to an ecosystem or
        the loss of an endangered species. Assess any effects of
        this action which would be cumulative to those of other
        similar, existing projects or proposed actions

3.2 3   Socio-Economic Considerations -- Discuss the effect on the
        local socio-economic development in relation to labor, hous-
        ing and population growth trends, relocation, local industry
        and industrial growth, and public service Describe the
        benefit ial effects, both direct and indirect, of the action
   on the human environment such as economic benefits resulting

from the services and products, energy, and other results of the action (include tax benefits to local and state governments, growth in local tax base from new business and housing developments, and payrolls) Describe impacts on human elements, including any need for increased public service (schools, police and fire protection, housing, waste disposal, markets, transportation, communication and and recreational facilities) Indicate the extent to which maintenance of the area is dependent upon new sources of energy or the use of such vital resources as water.

3.2.4   Air and Water Environment -- Assess the impact on present air quality due to process discharge quantities, and other discharging operational units Assess the impact on present noise levels due to project-related noises. Assess the impact on present water quality, including sedimentation, due to cooling or heating system discharges, process effluents, sanitary and waste effluents, water use for hydrostatic testing, and water use for other operational units.

3.2.5   Solid Wastes -- Describe any impacts from accumulation of solid wastes and by-products that will be produced

3.2.6   Use of Resources -- Quantify the resources necessary for operational processes, e g , water (human needs and processes), energy requirements, raw products, and specialized needs. Assess the impact of obtaining and using these resources

3.2.7   Maintenance -- Discuss the impact of maintenance programs, such as subsequent clearing or treatment of rights-of-way and hydrostatic testing and shutdowns. Discuss the potential impact of major breakdowns and shutdowns of the facilities and how service will be maintained during shutdowns.

3.2.8   Accidents and Catastrophes -- Describe any impacts resulting from accidents and natural catastrophes, which might occur, and provide an analysis of the capability of the area to absorb predicted impacts

3.3   TERMINATION AND ABONDONMENT -- Discuss the impact on land use and aesthetics of the termination and/or abandonment of facilities resulting from the proposed action.

III   Examples of Descriptive Checklists

A   Construction Engineering Research Laboratory (5)

1.   Sequence of events for filing an EIS is shown in Figure 1

-18-
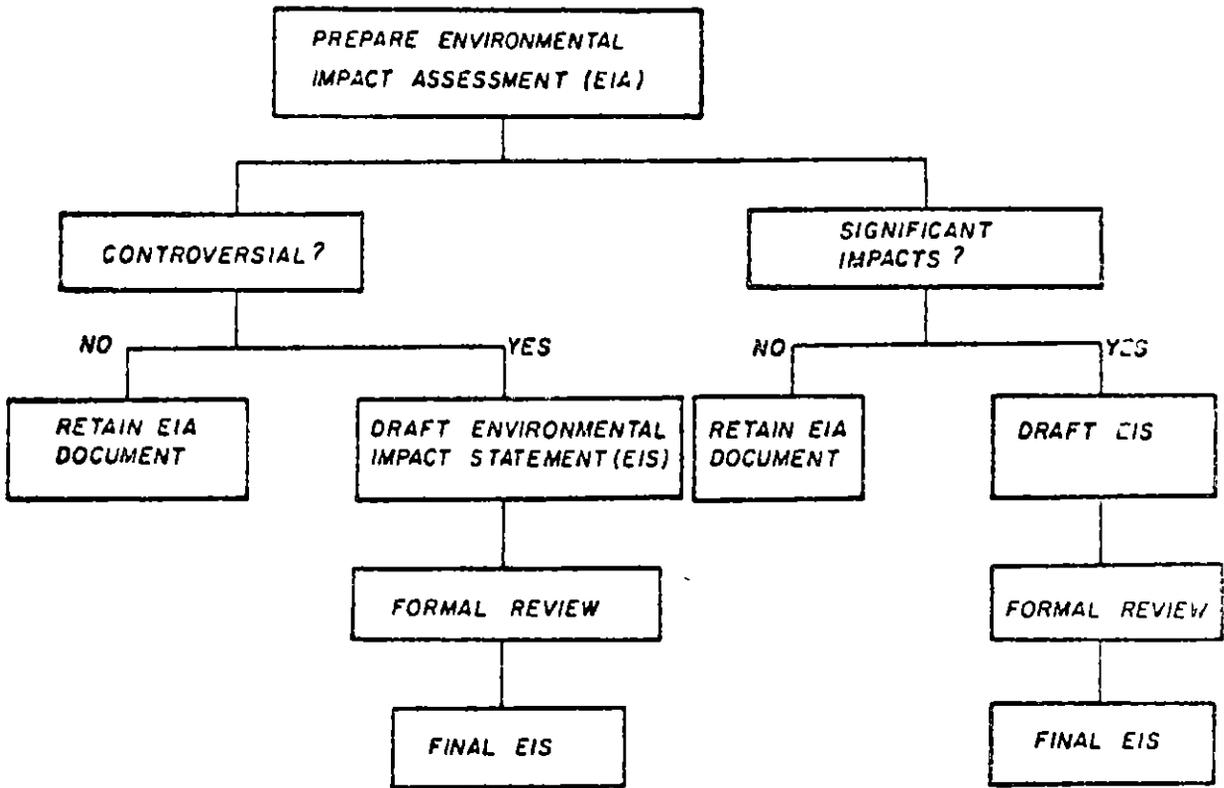
Summary Figure 1 Flow of environmental impact assessments
and statements and their interrelationship

2. The activities of the Army are organized into nine functional areas as follows

   i   construction

   b   operation, maintenance and repair

   c   training

   d.   mission change

   e.   real estate

   f.   procurement

   g.   Army industrial activities

   h   research, development, test and evaluation (RDT&E)

   i.   administration and support

3. Each functional area has a number of Basic Activities associated with implementing an Army Program (BAAP). Some examples of BAAPs in the construction functional area include clearing trees, removing broken concrete, backfilling foundation, curing bituminous pavement, cleaning used concrete forms, installing insulation and landscaping site, a total of about 2,000 BAAPs are identified in all nine functional areas.

4 The environment is divided into 11 broad areas or technical specialties as follows

   a.   ecology

   b.   health science

   c   air quality

   d   surface water

   e.   groundwater

   f   sociology

g   economics

h   earth science

ʟ   land use

ɪ   noise

k   transportation

5   Within each of the 11 areas, three types of factors, or attributes,
were identified.

    ȧ   Detailed attributes were the finest level of separation within

        each area   For example, in the area of Ecology detailed at-

        tributes included Rare or Endangered Animal Species, Food

        Webs, Warm Water Fishing and Noxious Weeds, in the area of

        Surface Water   Turbidity, Biochemical Oxygen Demand, Phos-

        phorous and Mercury, and in Sociology   Residence Distribution,

        Ethnic Composition, Landscape Amenities and Conflicting Land

        Uses   Obviously, there is interaction between these areas,

        and the pollutants affect many types of uses of the environ-

        ment, not just one at a time. About 1,000 detailed attributes

        have been developed at this time for all scientific disciplines

    b   Review level attributes are broader and more inclusive in

        scope than detailed level attributes, but are not necessarily

        simply aggregations of the lower level   Some potential users

        of the completed system need the sort of overview which this

        smaller number of more important attributes will provide. Ex-

        amples of review level attributes are   Resource Base, Patho-

        genic Organisms, and Increase in Undesirable Species--from the

        areas of Sociology, Surface Water and Ecology, respectively

        About 100 review level attributes are currently utilized.

c. <u>Controversial attributes</u> identify those areas which the
   scientists feel will arouse public opposition to a proposed
   program Scientifically, they may not represent the great-
   est environmental threats, but may merely be particularly
   sensitive areas. Impacts on Game Animals, Oil Spills and
   Amenity Elements are three examples from Ecology, Surface
   Water and Sociology, respectively. About 50 particularly
   sensitive areas are identified.

6. See Figures 2-12 for a general delineation of environmental
   attributes.

7. Consideration was then given to the impact of the approximately
   2,000 BAAP's on the 1,000 detailed attributes. Each potential
   impact was placed in one of four categories.

   a. This potential impact must be assessed every time the
      activity is carried out.

   b. This impact is usually present, but may be omitted depending
      on individual circumstances.

   c. This impact arises in a small but predictable number of cases.
      Consider it to see if it is present in your case.

   d. (blank) There is usually no impact upon this attribute by
      this activity.

      The a, b, c, and "blank" markings are called the "need-to-
      consider" scale. All this information is stored in the CERL
      Environmental Impact Computer System. (EICS). (6)

8. The EICS functions as follows A user identifies his project and/or
   gives its facility class code. Certain impacts are associated with

Figure 2 Attribute Hierarchy for Ecology
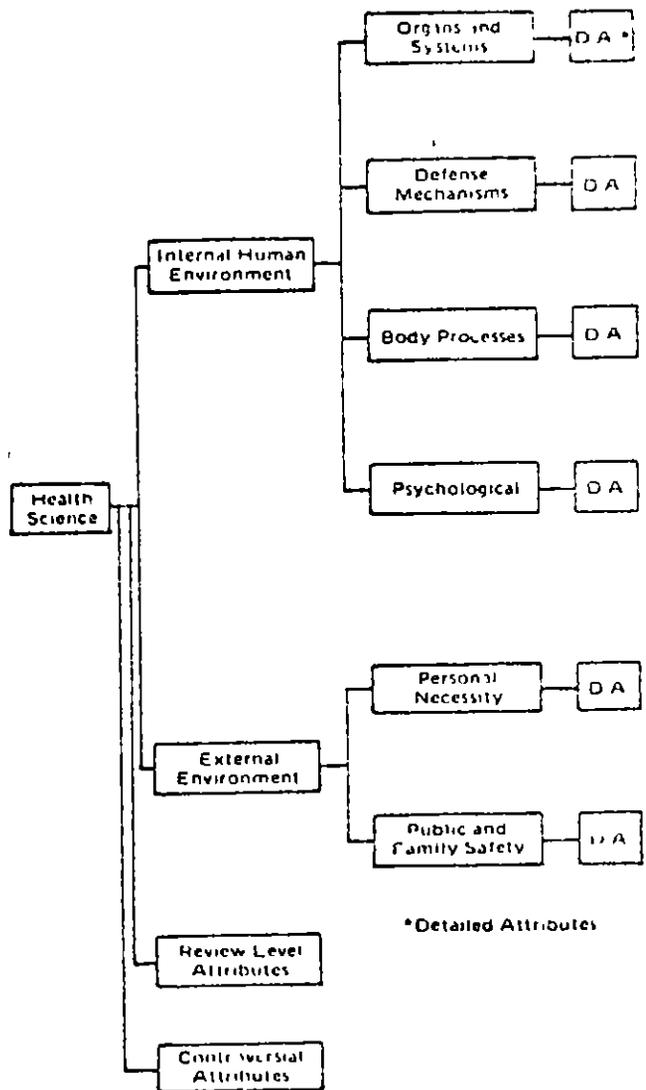
Figure 3 Attribute Hierarchy for Health Science
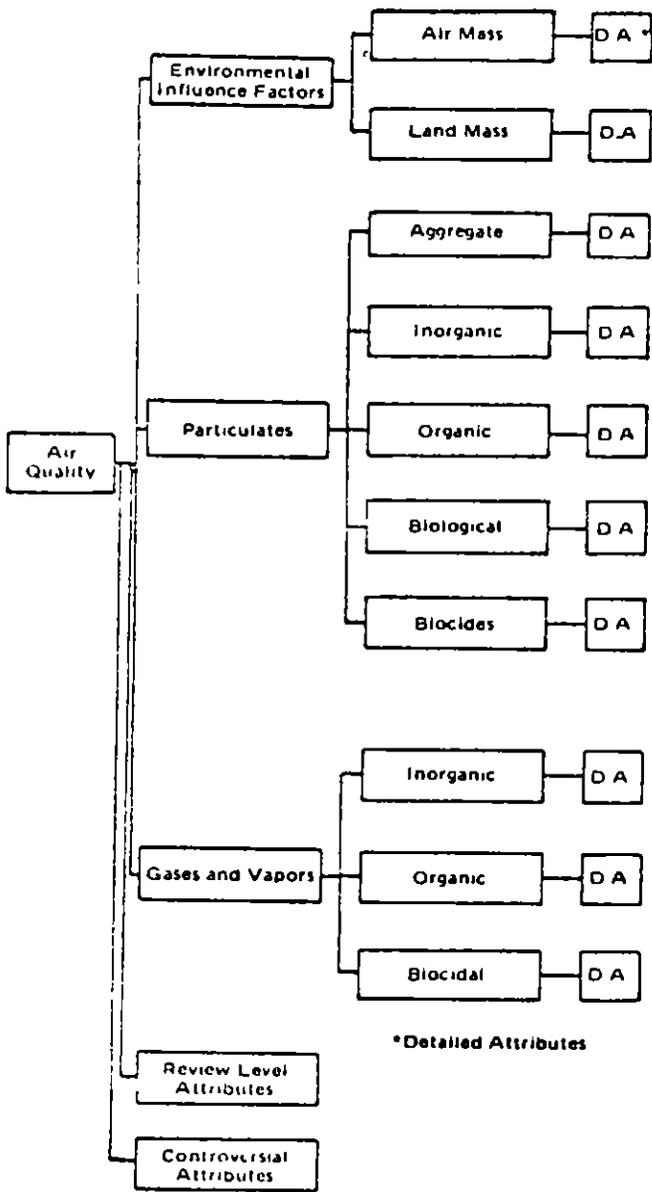
Figure 4. Attribute Hierarchy for Air Pollution
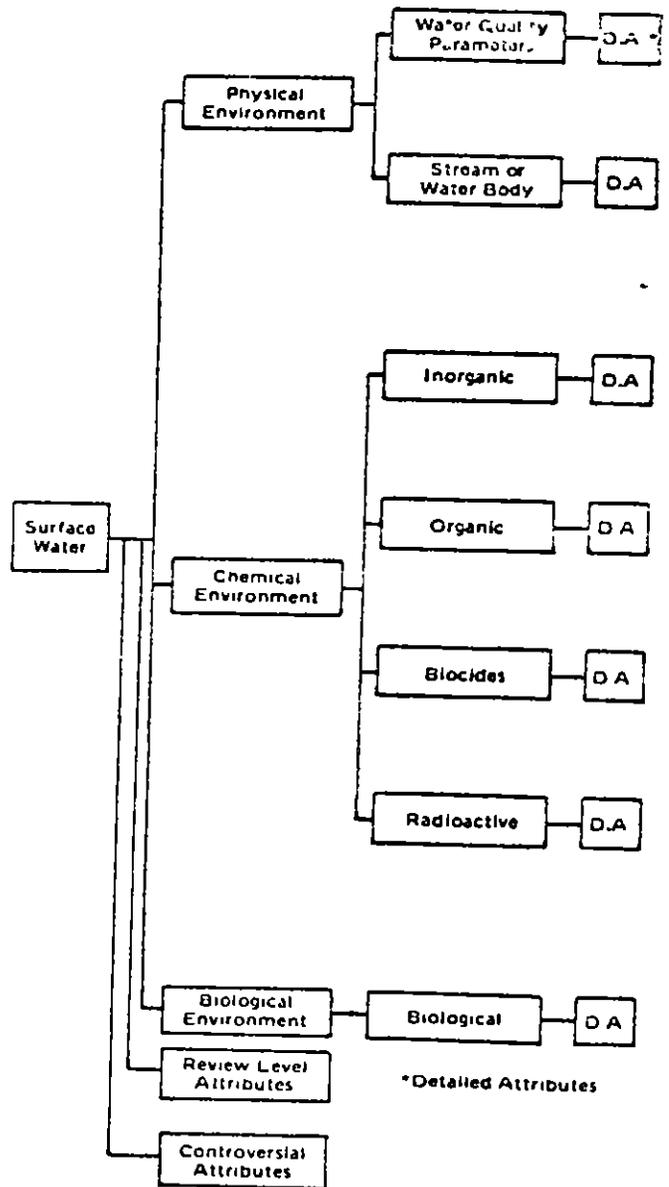
Figure 5. Hierarchy of Surface Water Attributes
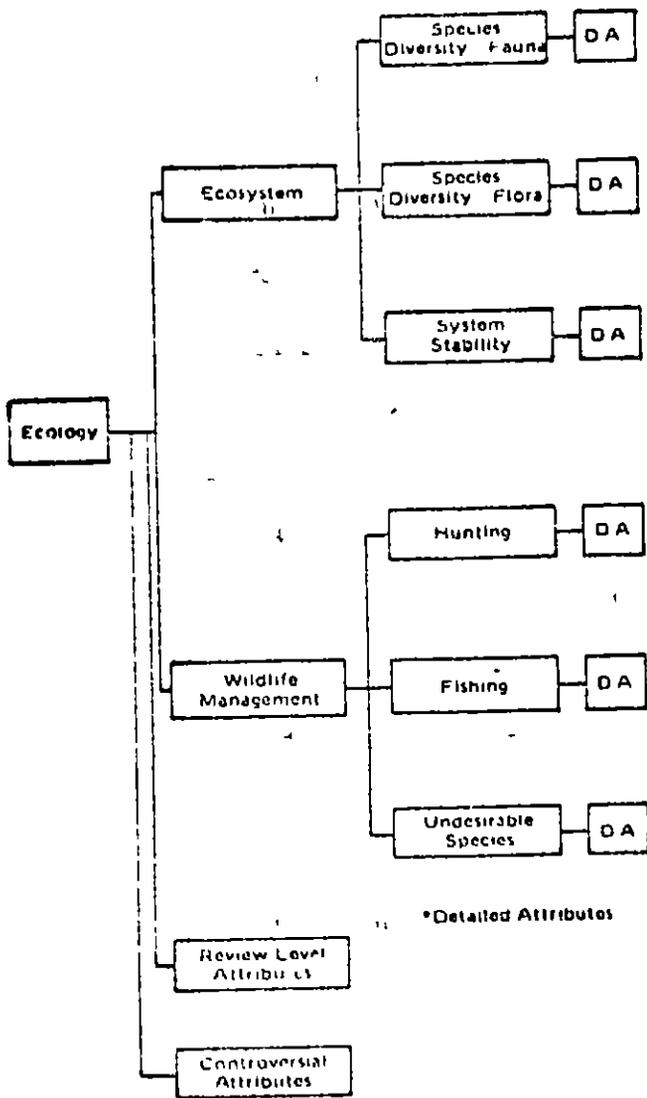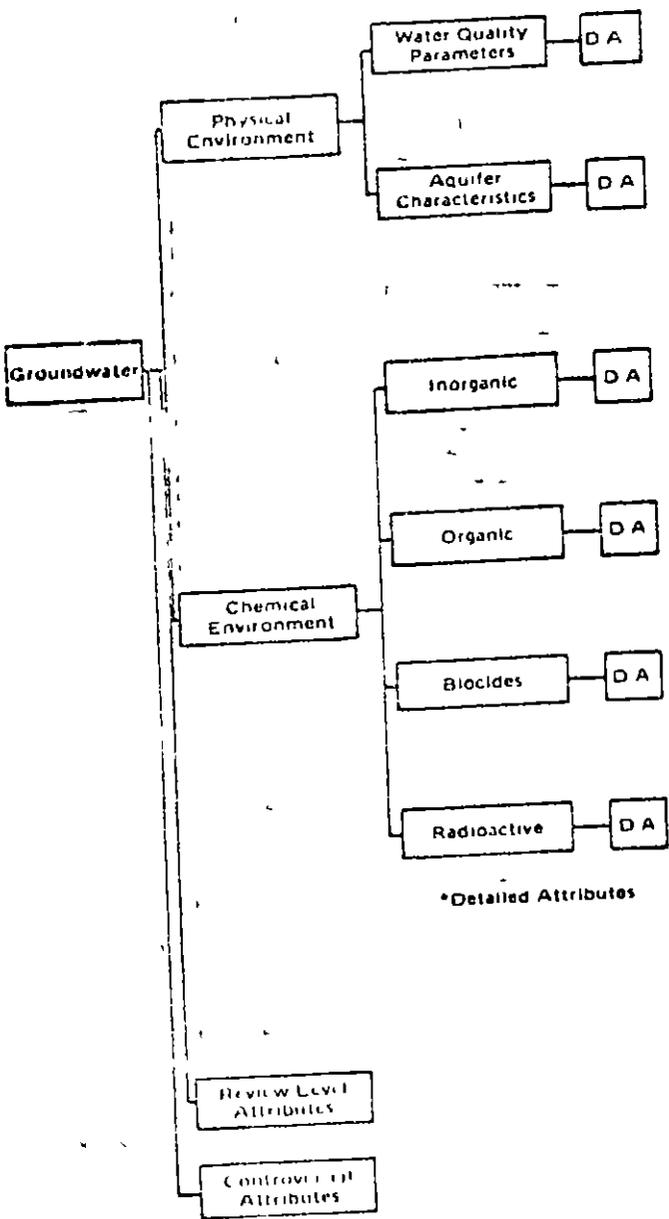
Figure 6. Attribute Hierarchy for Ground water
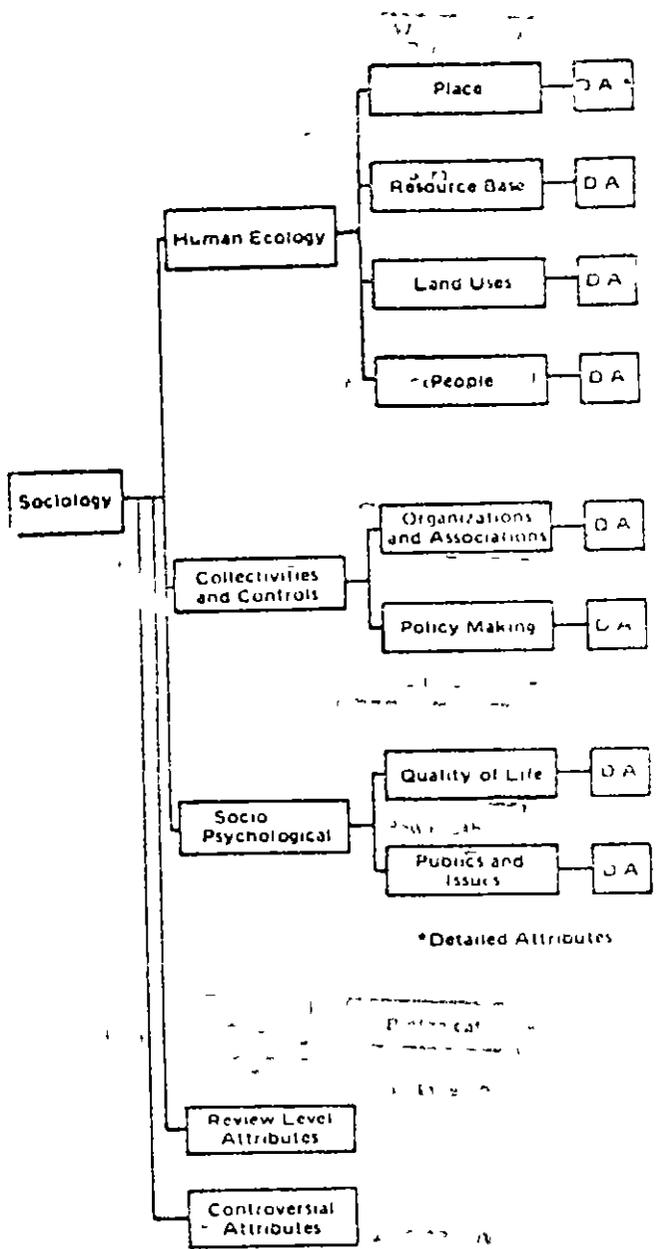
Figure 7. Attribute Hierarchy for Sociology
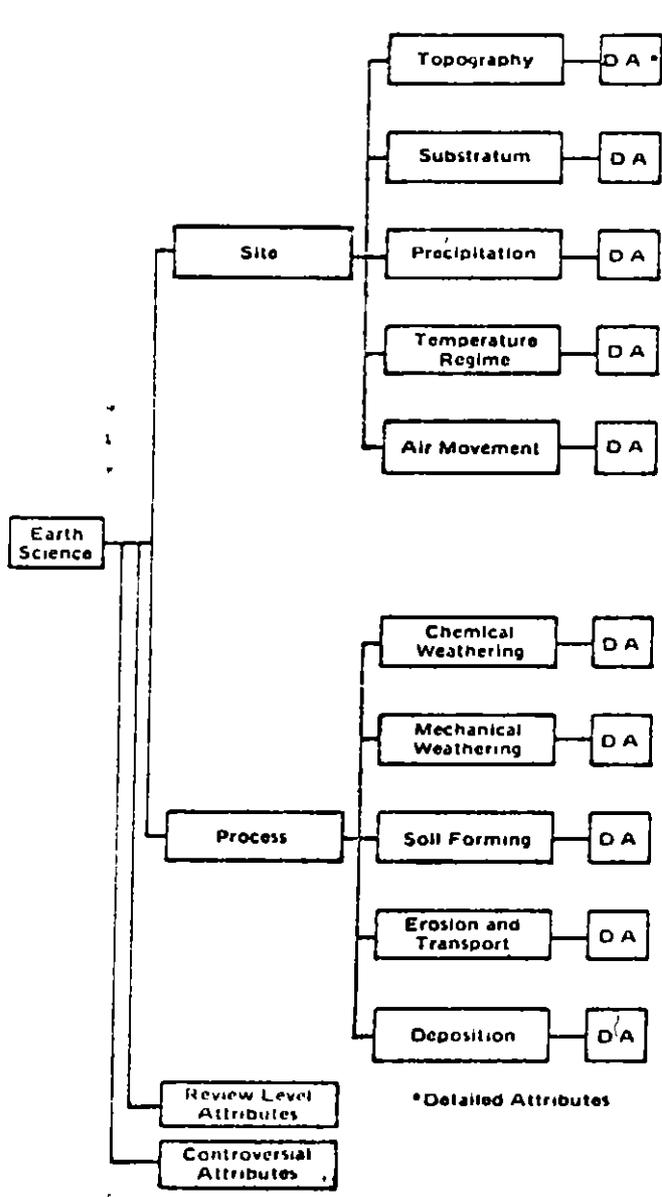
Figure 9. Attribute Hierarchy for Earth Science
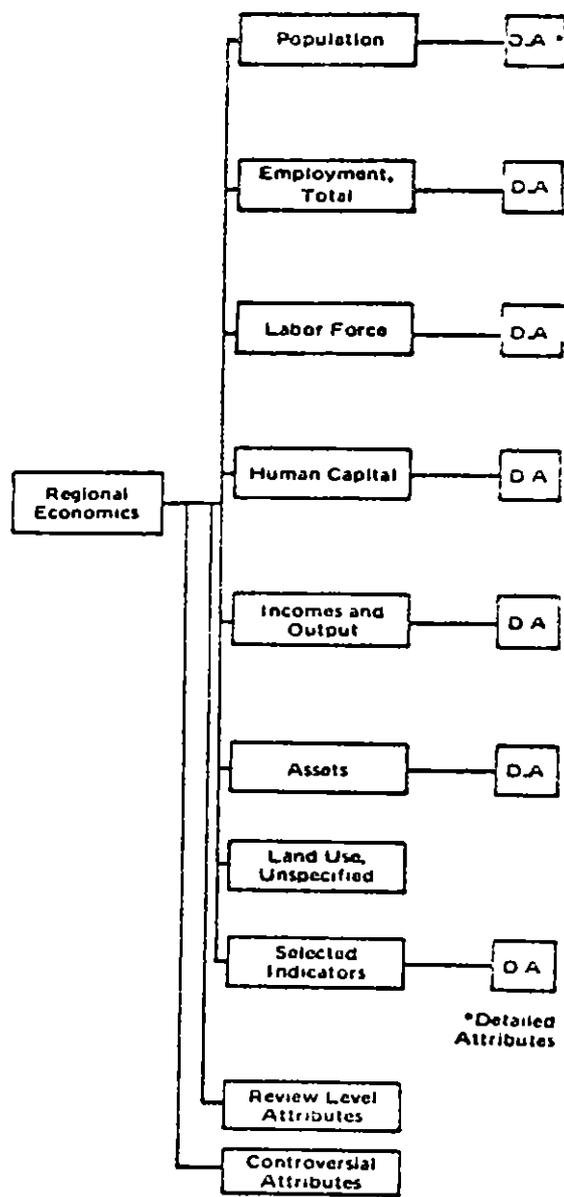
Figure 8. Attribute Hierarchy for Regional Economics
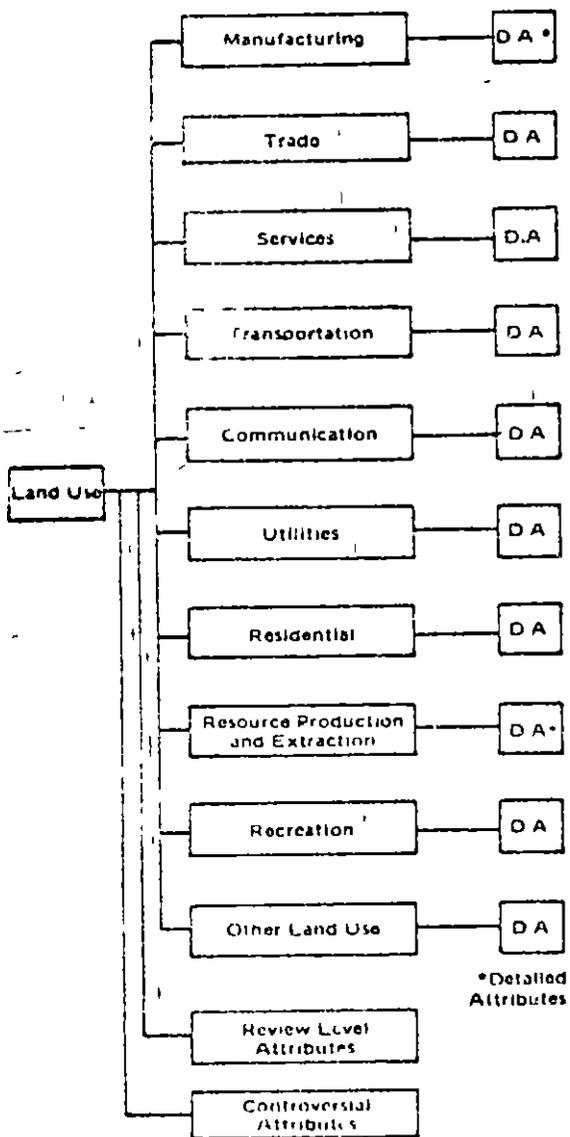
Figure 10. Attribute Hierarchy for Land Use
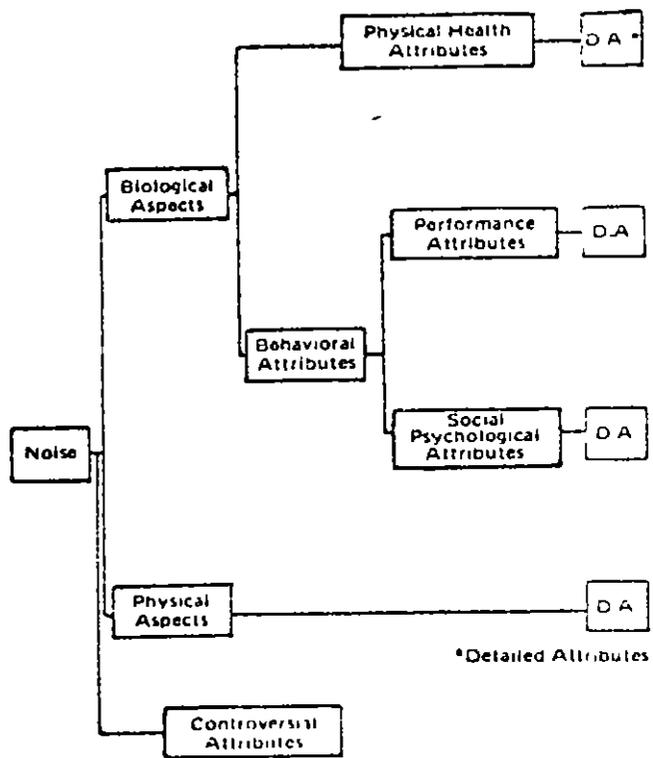
Figure 11. Noise Attribute Hierarchy
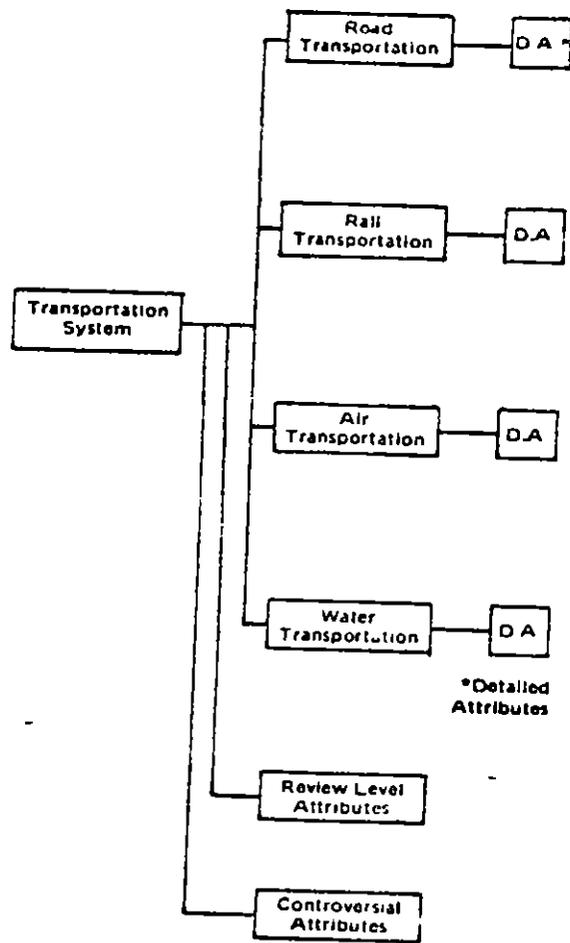
Figure 12. Attribute Hierarchy for Transportation

each construction activity, and the program searches out all those impacts caused by activities utilized in performing a type of project   At present, the computer output is in a matrix format, listing impacting activities on one axis and impacted attributes along the other. The "need to consider" marking appears at their intersection. The attributes may include all levels, or, at the user's option, only the review level   Controversial attributes are printed in all cases   See Figure 13

9   Ramification remarks are also included in the print-out   These are included to help explain some impacts. For example, a ramification remark may call attention to the fact that the reason grading a parking lot impacts fish populations is due to erosion of the bare soil, subsequent turbidity of the water, and eventual siltation of breeding sites on the lake bottom.

10   Mitigation procedures for impacts are also included in the print-out   In the example of the erosion from the graded site mentioned above, construction of a check dam or temporary settling pond could be recommended.

B.   Atomic Energy Commission (7)

1   Ch. 4 in the basic Regulatory Guide requires a discussion of the expected effects of site preparation and plant and transmission facilities construction on the environment   As an example, the following deals with transmission facilities construction (Sec 4 2)

>   The effects of construction and installation of
>   transmission line towers and facilities on the
>   land and on the people, including those living
>   in and those visiting or traveling through the
>   adjacent area, should be discussed in this Sec-
>   tion. (Refer to Section 3.9 for the basic in-
>   formation)

-29-

BAAP's	Alternate Methods of Accomplishing the Activity	Technical Specialty Water Quality					Ramifications	Mitigation Techniques
		Turbidity	Gross Solids	Floating Solids	DO	—Attributes		
Channel Excavation	Drag line front end loader back hoe dozer, hand	A*	B	C	A			

*A, B and C are need to-consider scales

Figure 13. Typical Impact Matrix For a Technical Specialty

The following topics may serve as guidelines for this discussion but the applicant should include additional material if it is relevant

a. Any permanent changes that will be induced in the physical and biological processes of plant and wildlife through the changes in the hydrology, topography or ground cover or through the use of growth retardants, chemicals, biocides, sprays, etc during construction and installation of the transmission lines

b Total length of new lines through and in various categories of visually sensitive land (this is sensitive to presence of transmission lines and towers) such as natural shoreline, marshland, wildlife refuges, parks, national and state monuments, scenic areas, recreational areas, historic areas, national forests and/or heavily timbered areas, shelter belts, steep slopes, wilderness areas.

c. Number and length of new access and service roads required.

d. Erosion directly traceable to construction activities

e Loss of agricultural productivity on right-of-way

f. Mitigative measures such as plans for protection of wildlife, for disposal of slash and unmerchantable timber, and for cleanup and restoration of area affected by clearing and construction activities

Briefly discuss the effects of construction on any identified rare or endangered species and what action will be taken to mitigate any adverse effects.

2 Ch 5 deals with the environmental effects of plant operation

The topics include.

5 1 Effects of operation of heat dissipation system.

5 2 Radiological impact on biota other than man.

3. Specific example from Sec. 5.6

> The environmental effects of operation and
> maintenance of the transmission system re-
> quired to tie in the proposed facility to
> the pre-existing network should be evalu-
> ated The evaluation of effects should
> make clear the applicant's plans for main-
> tenance of the right-of-way and required
> access roads Plans for use of herbicides
> and pesticides should indicate types, vol-
> ume, concentrations, and manner and frequency
> of use Resulting effect on plant life,
> wildlife habitat, land resources, and scenic
> values should be evaluated

> New access roads may increase the exposure
> of transmission corridors to the public.

The applicant should consider the potential
effects of this increased exposure on resi-
dent wildlife.

This Section of the Report should also ref-
erence the applicant's estimate of any elec-
trical effects of potential environmental
significance which were previously identi-
fied and discussed in Section 3.9.

4. Table 5 presents a detailed description of the environmental

factors and units of parameter measurement to be used in com-

paring alternative plant systems.

IV. Examples of Scaling Checklists

A. Adkins and Burke (8)

1. This method was developed for transportation projects. It

basically consists of a checklist and scaling of impacts of

alternatives on a relative basis from -5 to +5 (+5 is the high-

est score).

2. A listing of the environmental factors with a definition or

explanation is included in Table 6.

3. An example of the use of the system for the environmental por-

tion of the checklist is in Table 7, and a summary of the results

from each portion is in Table 8.

4. The rating system can be put into full use only after extensive

information has been developed through observation and analysis

Furthermore, the final ratings may well be the result of a recur-

sive procedure in the planning of a freeway location and design

In other words, as the evaluation of alternatives is being made,

there is continuous discovery of ways to improve location and design. It

Table 5 ENVIRONMENTAL FACTORS TO BE USED IN COMPARING ALTERNATIVE PLANT SYSTEMS

Primary Impact	Population or Resources Affected	Description	Unit of Measure[1]	Method of Computation
1 Natural surface water body	(Specify natural water body affected)			
1 1 Impingement or entrapment by cooling water intake structure	1 1 1 Fish[2]	Juveniles and adults are subject to attrition	Percent of harvestable or adult population destroyed per year for each important species	Identify all important species as defined in Sect 2 7 Estimate the annual weight and number of each species that will be destroyed (For juveniles destroyed only, the expected population that would have survived naturally need be considered) Compare with the estimated weight and number of the species population in the water body
1.2 Passage through or retention in cooling systems	1 2 1 Phytoplankton and zooplankton	Plankton population (excluding fish) may be changed due to mechnical, thermal and chemical effects	Percent changes in production rates and species diversity	Field studies are required (1) to estimate the diversity and production rates of readily recognizable groups (e g diatoms green algae zooplankton) and (2) to estimate the mortality of organisms passing through the condenser and pumps Include indirect[3] effects which affect mortality
	1 2 2 Fish	All life stages (eggs, larvae, etc) which reach the condenser are subject to attrition	Percent of harvestable or adult population destroyed per year for each important species	Identify all important species as defined in Sect 2 7 Estimate the annual weight and number of each species that will be destroyed (For larvae eggs and juveniles destroyed only the expected population that would have survived naturally need be considered) Compare with the estimated weight and number of the species population in the water body
1.3 Discharge area and thermal plume	1 3 1 Water quality, excess heat	The rate of dissipation of the excess heat primarily to the atmosphere will depend on both the method of discharge and the state of the receiving water in respect to ambient temperature and water currents	Acres and acre-feet	Estimate the average Btu s per hour dissipated to the receiving water at full power Estimate the water volume and surface areas within differential temperature isotherms of 2° 3° and 5°F under conditions that would tend with respect to annual variations to maximize the extent of the areas and volumes
	1 3 2 Water quality, oxygen availability	Dissolved oxygen concentration of receiving waters may be modified as a consequence of changes in the water temperature, the translocation of water of different quality, and aeration	Acre feet	Estimate volumes of affected waters with concentration below 5 3 and 1 ppm under conditions that would tend to maximize the impact
	1 3 3 Fish (nonmigratory)	Fish[2] may be affected directly or indirectly[3] due to adverse conditions in the plume	Net effect in pounds per year (as harvestable or adult fish by species of interest)	Field measurements are required to establish the average number and weight (as harvestable or adults) of important species (as defined in Sect 2 7) Estimate their mortality in the receiving water from direct and indirect[3] effects

[1] Applicant may substitute an alternative unit of measure where convenient Such a measure should be related quantitatively to the unit of measure shown in this table

[2] "Fish" as used in this table includes shellfish and other aquatic invertebrates harvested by man

[3] Indirect effects could include increased disease incidence, increased predation, interference with spawning, changed metabolic rates hatching of fish out of phase with food or etc

Primary Impact	Population o Resource Affected	Description	Unit of Measure[*]	Method of Computation
	1 3 4 Fish (migratory)	Suitable habitats (wetland or water surface) may be affected	Acres of defined habitat or nesting area	Determine areas of suitable habitats because of the mill discharges including effects on food resources Document estimates of affected population by species
	1 3 5 Wildlife (including buds aquatic and amphibious mammals and reptiles)	A thermal barrier may inhibit migration, both hampering spawning and diminishing the survival of returning fish	Pounds per year (as adult or harvestable fish by species of interest)	Estimate the fraction of the stock that is prevented from reaching spawning grounds because of plant operation Prorate this directly to a reduction in current and long term fishing effort supported by that stock Justify estimate on basis of local migration patterns experience at other sites and applicable State standards
1 4 Chemical effluents	1 4 1 Water quality, chemical	Water quality may be impaired	Acre feet, %	The volume of water required to dilute the average daily discharge of each chemical to meet applicable water quality standards should be calculated Where suitable standards do not exist use the volume required to dilute each chemical to a concentration equivalent to a selected lethal concentration for the most important species (as defined in Sect 2 7) in the receiving waters The ratio of this volume to the annual minimum value of the daily net flow, where applicable of the receiving waters should be expressed as a percentage and the largest such percentage reported Include the total solids if this is a limiting factor Include in this calculation the blowdown from cooling towers
	1 4 2 Fish	Aquatic populations may be affected by toxic levels of discharge chemicals or by reduced dissolved oxygen concentrations	Pounds per year (by species as fish)	Total chemical effect on important species of aquatic biota should be estimated Biota exposed within the facility should be considered as well as biota in receiving waters Supporting documentation should include reference to applicable standards chemicals discharged and their toxicity to the aquatic populations affected
	1 4 3 Wildlife (Including birds, aquatic and amphibious mammals and reptiles)	Suitable habitats for wildlife may be affected	Acres.	Estimate the area of wet land or water surface impaired as a wildlife habitat because of chemical contamination including effects on food resources Document estimates of affected population by species
	1 4 4 People	Recreational water uses (boating, fishing, swimming) may be inhibited	Lost annual user days and area (acres) or shore line miles for dilution	Volume of the net flow to the receiving waters required fo dilution to reach accepted water quality standards must be determined on the basis of daily discharge and converted to either surface area or miles of shore Cross section and annual minimum flow characteristics should be incorporated where applicable Annual number of visitors to the affected area or shoreline must be obtained This permits estimation of lost user days on an annual basis Any possible eutrophication effects should be estimated and included as a degradation of quality

[*] See footnotes at beginning of table

Primary Impact	Population or Resource, Affected	Description	Unit of Measure[1]	Method of Computation
1.5 Radionuclides discharged to water body	1.5.1 Aquatic organisms	Radionuclide discharge may introduce a radiation level which adds to natural background radiation	Rad per year	Sum dose contributions from radionuclides expected to be released
	1.5.2 People, external	Radionuclide discharge may introduce a radiation level which adds to natural background radiation for water users	Rem per year for individual, man-rem per year for estimated population as of the first scheduled year of plant operation	Sum annual dose contributions from nuclides expected to be released. Calculate for above-water activities (siting fishing boating), in-water activities (swimming), and shoreline activities
	1.5.3 People, ingestion	Radionuclide discharge may introduce a radiation level which adds to natural background radiation for ingested food and water.	Rem per year for individuals (whole body and organ) man rem per year for population as of first scheduled year of plant operation	Estimate biological accumulation in foods, and intake by individuals and population. Calculate doses by summing results for expected radionuclides.
1.6 Consumptive use	1.6.1 People	Drinking water supplies drawn from the water body may be diminished.	Gallons per year	Where users withdraw drinking water supplies from the affected water body, lost water to users should be estimated. Relevant delivered costs of replacement drinking water should be included
	1.6.2 Agriculture	Water may be withdrawn from agricultural usage and use of remaining water may be degraded	Acre feet per year	Where users withdrawing irrigation water are affected the loss should be evaluated as the sum of two volumes: the volume of the water lost to agricultural use and the volume of dilution water required to reduce concentrations of dissolved solids in remaining water to an agriculturally acceptable level
	1.6.3 Industry	Water may be withdrawn for industrial use.	Gallons per year	
1.7 Plant construction (including site preparation)	1.7.1 Water quality, physical	Turbidity, color or temperature of natural water body may be altered	Acre feet and acres	The volume of dilution water required to meet applicable water quality standards should be calculated. The extent of the effect should be estimated
	1.7.2 Water quality, chemical	Water quality may be impaired	Acre-feet, %	To the extent possible the applicant should treat problems of spills and drainage during construction in the same manner as 1.4.1

-36-

Primary ect	Population c Resource s Affected	Description	Unit of Measure[1]	Method of Comb... on
1.8 Other im... s				The applicant ... est ... a ... f... o...r ... ...mental effects of th... prop...sed pl... t ... rich are a gr ficant.
1.9 Combined or Inter active effects				Where evidence indicates that the combined effect of a number of impacts on a particular population or resource is not adequately indicated by measures of the separate impacts the total combined effect should be described. See discussion in Section 5 8
1.10 Net effects				

...

Primary Impact	Population or Resources Affected	Description	Unit of Measure[1]	Method of Computation
2. Ground Water				
2 1 Raising/lowering of ground water levels	2 1 1 People	Availability or quality of drinking water may be decreased and the functioning of existing wells may be impaired	Gallons per year	Volume of replacement water for local wells actually affected must be estimated
	2 1 2 Plants	Trees and other deep-rooted vegetation may be affected	Acres	Estimate the area in which ground water level charge may have an adverse effect on local vegetation Report this acreage on a separate schedule by land use Specify such uses as recreational agricultural and residential
2 2 Chemical contamination of ground water (excluding salt)	2 2 1 People	Drinking water of nearby communities may be affected	Gallons per year	Compute annual loss of potable water
	2 2 2 Plants	Trees and other deep-rooted vegetation may experience toxic effects	Acres	Estimate area affected and report separately by land use Specify such uses as recreational, agricultural and residential
2 3 Radionuclide contamination of ground water	2 3 1 People	Radionuclides which enter ground water may add to natural background radiation level for water and food supplies	Rem per year for individuals (whole body and organ) man rem per year for population as of year of first scheduled year of plant operation	Estimate intakes by individuals and populations Sum dose contributions for nuclides expected to be released
	2 3 2 Plants and animals	Radionuclides which enter ground water may add to natural background radiation level for local plant forms and animal population	Rad per year	Estimate uptake in plants and transfer to animals Sum dose contributions for nuclides expected to be released
2 4 Other impacts on ground water				The applicant should describe and quantify any other environmental effects of the proposed plant which are significant

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Factor	Population of Receptor	Description	Unit of Measure	Method of Computation
3 A				
3 1 Icing and icing (caused by evaporation and drift)	3 1 1 Ground transport	Safety hazards may be created in the nearby regions in all seasons	Vehicle hours per year	Compute the number of hours per year that driving hazards will be increased on paved highways by fog and ice from cooling towers and ponds. Documentation should include the visibility criteria used for defining hazardous conditions on the highways actually affected
	3 1 2 Air transportation	Safety hazards may be created in the nearby regions in all seasons	Hours per year, flights delayed per year	Compute the number of hours per year the control airports will be closed to visual (VFR) and instrumental (IFR) air traffic because of fog and ice from cooling towers. Estimate number of flights delayed per year
	3 1 3 Water transportation	Safety hazards may be created in the nearby regions in all seasons	Hours per year number of ships affected per year	Compute the number of hours per year ships will need to reduce speed because of fog from cooling towers or ponds or warm water added to the surface of the river, lake or sea
	3 1 4 Plants	Damage to timber and crops may occur through introduction of adverse conditions	Acres by crop	Estimate the acreage of potential plant damage by crop
3 2 Chemical discharge to atmosphere	3 2 1 Air quality, chemical	Pollutant emissions may diminish the quality of the local ambient air	% and pounds or tons	The actual concentration of each pollutant in ppm for maximum expected emission rate should be expressed as a percentage of the applicable emission standard. Report weight for expected annual emissions
	3 2 2 Air quality odor	Odor in gaseous discharge or from effects on water body may be objectionable	Statement	A statement must be made as to whether odor originating in plant is perceptible at any point off-site
3 3 Radionuclides discharged to ambient air and due to radiation from radioactive materials (in plant or being transported)	3 3 1 People external	Radionuclide discharge or direct radiation may add to natural background radiation level	Rem per year for individuals (whole body and organ) man rem per year for population as of year of first scheduled operation	Sum dose contributions from nuclides expected to be released
	3 3 2 People ingestion	Radionuclide discharge may add to the normal radioactivity in vegetation and in soil	Rem per year for individuals (whole body and organ) rem per year for	

Primary I...	Pon... ... Re...	Description	Unit of Measure	... of Computati...
			po... ...n ... of year of fu... scheduled o...ration	
	3.3 3 Plants and animals	Radionuclide discharge may add to natural background radioactivity of local plant and animal life	Rad per year	Estimate deposit of radionuclides on and uptake in plants and animals. Sum dose contributions for radionuclides expected to be released
3.4 Other impacts on ...				The applicant should describe and quantify any other environmental effects of the proposed plant which are significant

*Section ... of t... ...ng of ...

-40-

Primary Impact	Factor and Resource ...	Description	Unit of Measure	... Criteria ...
4 Land				
4 1 Site selection	4 1 1 Land amount	Land will be preempted for construction of nuclear power plant plant facilities, and exclusion zone	Acres	State amount of land ... to ... zone, and a ... ... fuel ... such as cooling ... ponds By separate schedule state the type and class of land preempted (e.g scenic shoreline wet land forest land etc)
4 2 Construction activities (including site preparation)	4 2 1 People (amount ...)	There will be a loss of desirable qualities in the environment due to the noise and movement of men material and machines	Total population affected, y... 2	The disruption of community life (or alternately the degree of community isolation from such ... should be estimated Estimate the number of re... ... schools hospitals etc with n area of visual and audio impacts Estimate the duration of impacts and total population affected
	4 2 2 People (accessibility of historical sites)	Historical sites may be affected by construction	Visitors ...	Determine historical sites that might be disrupted by generation facilities Estimate effect on any other sites in plant environs Express net impact in terms of annual number of visitors
	4 2 3 People (accessibility of archeological sites)	Construction activity may impinge upon sites of archaeological value	Qualified opinion	Summarize evaluation of impact on archeological resources in term of remaining potential value of the site Referenced documentation should include statements from responsible agency S ... of ... ... available
	4 2 4 Wildlife	Wildlife may be affected	Qualified opinion	Summarize qualified opinion including views of competent local and State wildlife agencies when available Take into account both beneficial and adverse affects
	4 2 5 Land (erosion)	Site preparation and plant construction will involve land fill operations with accompanying erosion potential	Cubic yards and acres	Estimate soil displaced by construction activity and erosion Beneficial and detrimental effects should be reported separately
4 3 Plant operation	4 3 1 People (stress)	Noise may induce stress	Number of residents, school populations hospitalized	Use the Proposed HUD Criteria Code for Noise Area for Noise to establish the ... in the categories of Clearly Unacceptable ... ... Unacceptable and Normally Acceptable For each ... separately the number of residences th ... 1 d ... ... of the ...
	4 3 2 Land (aesthetic)	The local land ... ... ed from adjacent residential areas and neighboring factor ... scenic and recreational sites may be rendered ...	Qualified opinion	Summarize ... ... of ... ... Explanatory ... ...

Fr	Popula o or Re o c 'n d	Description	Un	Method of Compu a o
		n s' e '} objectionable by the plant facility)		
	4 3 3 Wildlife	Wildlife may be affected	Qualified opinion	Summarize qualified opinion including views of c gnizant local and State wildlife agencies when available taking into account both beneficial and adverse effects
	4 3 4 Land flood control	Health and safety near the water body may be affected by flood control	Reference to Flood Control District approval	Reference must b made to regulations of cognizant Flood Control Agency by use of one of the following terms Has NO IMPLICATIONS for flood con of COMPLIES with flood control regulation
4 4 Salts d sch from cooling to r	4 4 1 People	Int usion of salts into groundwater may affect water supply	Pounds per square foot per year	Estimate the amount of salts discharged as dr ft and particulates Report maximum deposition Suppo ng documentation should include patterns of depos r and projection of possible effect on water supplies
	4 4 2 Plants and an m ls	Deposition of entrained salts may be detrimental in some nearby regions	Acres	Salt tolerance of local affected area vegetation must be determined That area if any receiving sal d p sition in excess of tolerance (afte allowance for dilu r n) m us be estimated Rep rt separately an appro, a e tabulation of acreage by land use Specify such u es as recre al agricultural an 'ntial W ere w ld e h a s affe d uer s po ions
	4 4 3 Property resources	Structures and movable property may suffer degradation from corrosive effects	Dollars per year	If salt spray impinges upon a local communty then property dam may be estimated by applying to l local value of buildings machinery and veh l s a differen l in average depreciation rates be ween this and a comparable sea coast community
4.5 Trans It on route s	4 5 1 Land amount	Land will be preempted for construction of transmission line systems	Miles, acres	State total length and area of new rights-of v a Est current market value of land involved
	4 5 2 Land u and Land r'	Lines may pass th ough visually c ns ve (that is sensitive to presence of t ans sion lines and towers) areas thus impr ng on their present and potential u and value of neighboring property	Miles, acres, dollars	Total length of n v transmio l s a s of right-of v ay through various categories of s l the land Estimate minimum loss in curre pr,) values of adjacent a eas
	4 5 3 People (a s th c)	Lines may p e it visually undesirable features	Number of su h features	Estim e total number of visually unde n fe ures such as number of major road cross es m y of intersection or interchanges number of majo v t y cro si s number of crest n c or othe h h p it c number of lon views of tra o b perpendi ular to h ghw ays and water a)

Primary Impact	Population or Resource Affected	Description	Unit of Measure	Method of Computation
4 6 Transmission facilities construction	4 6 1 Land adjacent to right-of-way	Co... for areas to right-of-way may have environmental impact	Acres	... of ... for alternative routes.
	4 6 2 Land erosion	Soil erosion may result from construction activities	Tons per year	Estimate area with increased erosion potential due to construction activities
	4 6 3 Wildlife	Wildlife habitat and access to habitat may be affected	Number of important species affected	Identify important (Sect 2 7) species that may be disturbed
	4 6 4 Flora	Flora may be affected		
4 7 Transmission line operation	4 7 1 Land Use	Land preempted by right-of-way may be used for additional beneficial purposes such as ... fields picnic areas nurseries, hiking and other trails	%, dollars	Estimate percent of right-of-way for which no multiple use activities are planned Annual value of multiple use activity less cost of improvements
	4 7 2 Wildlife	Modified wildlife habitat may result in changes	Qualified opinion	Summarize ... including views of concerned local and State wildlife agencies
4 8 Other impacts				The ... effects of ... significant
4 9 Combined or cumulative effects				Where evidence indicates that the combined effects of a number of impacts on a particular population or resource are not adequately indicated by measures of the separate impact the total combined effect should be ... Both beneficial and adverse interactions should be indicated
4 10 Net effects				See discussion in Section 5 8

Table 6   List of Environmental Factors
in Adkins-Burke Method

Factor	Definition or Explanation
TRANSPORTATION	Movement of people, goods and services
A. Local Area Service	Effects upon corridor area
1. Passenger cars	
(a) Circulation along freeway	Circuity of travel and congestion from freeway
(b) Circulation across freeway	Difficulty of getting back and forth across freeway
(c) Movements in and out of area	To other parts of city. How much of local area service
2. Trucks	
(a) Circulation along freeway	See 1 (a)
(b) Circulation across freeway	See 1 (b)
(c) Movements in and out of area	See 1 (c)
3 Public transit	Bus or other effects upon
(a) Service within local area	
(b) Service in and out of area	
4 Pedestrian movements	Circuity, safety, etc
(a) Work	
(b) Shopping	
(c) School	
(d) Church	
(e) Social or recreational	
(f) Other_____	

5. Railroad service	____ o improvement ___, etc
6. Airport	Interference or improvement
7. Waterway	Interference or improvement
8. Other _____	
B. Metropolitan Area Service	PPM 20-_ (1)
1. Via freeway system	Either route as part of system
(a) Passenger cars	
(b) Trucks	
(c) Public transit	
2. Via other streets	Effect if one freeway is built
(a) Passenger cars	
(b) Trucks	
(c) Public transit	
3. Railroad service	Improvement of interference
4. Airport access	Improvement or interference
5. Waterway effects	
6. Other _____	
II Environmental	NEPA and PPM 20-8
A. Community (Local Area)	
1. Noise pollution	Relation to present Levels PPM 20-8 p 3)
(a) Adjacent to freeway	
(b) General area	
2. Air Pollution	PPM 20-8 (p 3)
(a) Adjacent to freeway	
(b) General area	

3 Drainage	Effect on chances of flood , etc
(a) Adjacent to freeway	
(b) General area	
4 Water Supply	
(a) Water pollution	PPM 20-8 Permanent or serious temporary
(b) Water Quantity	Interference with movement or level of ground water
5. Waste disposal	PPM 20-8 Access to, interference, etc.
6. Flora effects	NEPA and PPM 20-8 and Irreplaceable losses, etc
7. Fauna effects	NEPA and PPM 20-8 Breeding or nesting, etc
8. Parks	PPM 20-8 Improvement or damage to
9. Playgrounds	PPM 20-8 Improvement or damage to
10. Archeological sites	NEPA and PPM 20-8 Loss of or access to, etc
11. Historical sites	PPM 20-8 Loss of or access to, etc.
12. Open space	
13. Visual aspects	PPM 20-8 Community view of freeway
(a) Adjacent to freeway	
(b) General area	
14. Safety	PPM 20-8 Any change in hazards
(a) Traffic	
(b) Pedestrian	
(c) Other_____	
15. Other_____	PPM 20-8 e.g., other resources

B. Freeway Motorist Experience	PPM 20-0
1. View of freeway	Appearance and security
2. View of adjacent area	Aesthetics or special sights
3. Panoramic views	Vistas
4. Area hazards	Hazards to freeway users and vehicles
III. SOCIOLOGICAL	Social relationships PPM 20-0
A. Community (Local Area)	PPM 20-0
1. Neighborhood severance	Violation of neighborhood boundaries
2. Cultural patterns	Ethnic cohesion, stability, life style
3. Crime	Assault, robbery, breaking, etc.
(a) Rate	Change in opportunity for
(b) Police protection	Availability and speed
4. Fire hazard	Type and density of land area PPM 20-0
(a) Hazards	Dwellings, trash, etc.
(b) Fire protection	Available equipment and time
5. Health	PPM 20-0
(a) Health factors	Sanitation, vigorous sports, etc.
(b) Medical services	Time to reach health facilities or obtain services
6. Religious service	PPM 20-0 Opportunity to att
(a) Loss of places	Removal of churches
(b) Access to	Isolation of members
7. Educational	Loss of or effect on access to
(a) Elementary	PPM 20-
(b) Junior H.S.	PPM 20-
(c) High School	PPM 20-0
(d) Trade and College	

8 Recreation & facilities	
9 Social services	
10 Public utilities	
11 Neighborhood livability	Pleasantness of surroundings
(a) Construction period	Disruption
(b) Long run	Cleanliness, repairs, etc
B. Metropolitan Area	loss of and effects on access to
1 Police protection	PPM 20-8
2 Fire protection	PPM 20-8
3 Medical services	PPM 20-8
4 Educational services	PPM 20-8
5 Parks	PPM 20-8
6. Recreation	PPM 20-8
7 Historical sites	PPM 20-8
8 National defense	PPM 20-8
(a) Evacuation	As a link in system
(b) Military movements	As a link in system
(c) Hazards to critical industry	
IV ECONOMIC IMPACT	
A Community (Local Area)	
1 Employment	PPM 20-8
(a) Construction period	Change in place or access
(b) Long run	Change in place or access

2. Shopping facilities	
(a) Construction period	...ry place or ...cenn
(b) Long run	...and loss of customers
3. Residential Values	PPM 20-S
4. Other Property Value	PPM 20-3
5. Property Tax Base	PPM 20-o
(a) Construction period	Loss of taxable values
(b) Long run	Potential for change
6. Displaced residents	PPM 20-o
(a) Owners	
(1) DSS housing	DSS = decent, safe and sanitary
(2) non-DSS housing	
(b) Renters	
(1) DSS housing	
(2) non-DSS housing	
(c) Ease of replacement	PPM 20-8
7. Displaced businesses	PPM 20-3
(a) Small businesses	
(1) Number	
(2) Number of jobs	PPM 20-o
(3) Ease of relocation	
(b) Other businesses	PPM 20-3
(1) Number	
(2) Number of jobs	PPM 20-3
(3) Ease of relocation	

-49-

8 Remaining businesses	Effects on jobs PPM 20-8
(a) Small businesses	and solvency
(1) Construction period	PPM 20-8
(2) Long run	PPM 20-8
(b) Other businesses	PPM 20-8
(1) Construction period	PPM 20-8
(2) Long run	PPM 20-8
9. New business	Potential for PPM 20-8
10. Multiple use of land	
B. Metropolitan Area	Outside of local area
1. Employment, access to	PPM 20-
2. Shopping, access to	PPM 20-8
3 Commercial activity	PPM 20 8
4. Property values and tax base	PPM 20 8

Table 7 Example of Adkins-Burke
Method in Environmental Category.

Factor	Definition or Explanation	Alternative			Comments
		1	2	3	
II ENVIRONMENTAL	NEPA and PPM 20-8				
A Community (Local area)					
1 Noise pollution	Relation to present levels PPM 20-8				
(a) Adjacent to freeway		-2	-1		Relief of street traffic helps offset
(b) General area		+2	+1		Improves due to scale of street traffic
2. Air Pollution	PPM 20-8				
(a) Adjacent to freeway		+2	+1		Relief of street traffic
(b) General area		+5	+2		Relief of street traffic
3. Drainage	Effects on chances of flooding, etc				
(a) Adjacent to freeway		+1	0		Rte 1 will help drainage
(b) General area		0	0		
4 Water Supply					
(a) Water pollution	PPM 20-8 Permanent or serious temporary	0	0		Little, if any, effect
(b) Water Quantity	Interference with flow and or level of ground water	0			Little, if any, effect
5. Waste disposal	PPM 20-8 Access to, interference, etc	0	0		Little, if any, effect
6. Flora effects	NEPA and PPM 20-8 and Irreplaceable losses, etc	0	0		Little, if any, effect
7. Fauna effects	NEPA and PPM 20-8 breeding or nesting, etc	0	0		Little, if any, effect

Factor	Definition or Explanation	Rating Alternative 1	2	3	Comments
6. Parks	PPM 20-8 Improvement or damage to	+5	+2		Improves access to
9. Playgrounds	PPM 20-8 Improvement or damage to	+5	0		Rte 1 improves access to
10 Archaological sites	NEPA and PPM 20-8 Loss of or access to, etc	0	0		None affected
11 Historical sites	PPM 20-8 Loss of or access to, etc	+2	+1		Improves access to
12. Open space		+3	+1		Opens area by removing structures, some undesirable
13. Visual aspects	PPM 20-8 Community view of freeway	✕	✕	✕	
(a) Adjacent to freeway		+3	+1		Thru proper treatment areas will be improved
(b) General area		+2	0		Rte 1 would help Rte. 2 not likely to help
14 Safety	PPM 20-8 Any change in hazards	✕	✕	✕	
(a) Traffic		+3	+1		Rte 1 given more relief to streets & removes rr
(b) Pedestrian		+5	+1		Rte. 1 more persons involved
(c) Other_____		-	-		
15 Other_____	PPM 20-8 e g., other resources				
B. Freeway Motorist Experience	PPM 20-8	✕	✕	✕	
1. View of freeway	Appearance and security	+3	+1		Rte 1 clearer and nicer view
2. View of adjacent area	Aesthetics or special sights	0	+1		Rte 2 could give special views on curves
3. Panoramic views	Vistas	+1	+3		Rte ? good. Rte 1 downtown area
4. Area hazards	Hazards to freeway users and vehicles	+3	-1		Rte. 1 would displace hazards Rte 2 would expose motorists to industrial area, etc.

PART II. Summary Rating

	Alternative 1	2	3		Alternative 1	2	3
No of plus ratings	15	12	___	Algebraic sum of ratings	44	15	___
No of minus ratings	1	2	___	Average of ratings	2.75	1.00	___
Ratio of plus ratings	94	86	___				

Table 8· Adkins-Burke Method·
Overall Comparison of Ratings

Part	n of Plus Ratings	No of Minus Ratings	Total No. of Ratings	Avg h-aic Score Ratings		
IA Transp., Local Area						
Alt 1	-7	6	-13	18		
Alt 2	4	2	6	1	.7	.7
Alt 3						
IB Transp., Metropolitan Area						
Alt. 1	3	6		34	1.00	4.2
Alt. 2	6		7	7		1.3
Alt. 3						
II Environmental						
Alt 1	15			44	5·	7
Alt. 2	12	2	14	14	5·	6
Alt 3						
IIIA. Socio, Community						
Alt 1	9	2	11	27	82	2.6
Alt. 2	6	3	9	-1	67	- 11
Alt 3						
IIIB Socio, Metropolitan Area						
Alt 1	9	0	9	31	1.10	3.4
Alt 2	6	1	7	7	.66	.0
Alt 3						
IV. Economic Impact						
Alt 1	15	14	29	27	.52	9·
Alt 2	11	14	25	-11	50	- 39
Alt. 3						
All Ratings						
Alt 1	63	23	86	181	73	2 10
Alt. 2	48	23	71	17	.65	
Alt. 3						

is suspected that very often when a badly rated item appears, its disadvantages can be cured or ameliorated at a favorable cost. The search for such items may characterize the decision process until the time of contracting (and perhaps beyond) Thus the rating system has a similar purpose to that of the check list except that it is intensified through more detailed evaluation.

5. The summaries for the parts of the form and the overall comparison develop a ratio of plus ratings This measure is considered to be at least as important in summing and briefing the results as is the average rating The absence of uniformly accepted criteria or standards for evaluation gives the algebraic sign of the rating great importance Similarly, the difficulty of quantification and aggregation of the factors makes the determination of magnitudes for the numerical ratings highly inexact. The ratings, however, do allow for the bringing to bear of more knowledge to bear than would positive and negative designations only.

6. The rating form allows for independent evaluations of two alternatives using the existing (including already assured changes and additions) street and road system as the base condition for each rating. Also only one series of ratings may be used, in which case the alternatives are rated against each other, again with a base condition of existing roads and streets.

7. Combining the recursive planning mentioned above with his prior knowledge, professional judgment, and familiarity with decision processes, the highway engineer-planner ordinarily will have

evolved a superior alternative by the time that final factor ratings are decided. In such a case, the two measures (the ratio of plus ratings and the average rating) should be highly compatible. Nevertheless, the trade-offs will be identified by negative numbers and their seriousness suggested. If the ratios of plus ratings are low (approaching .50), regardless of the average ratings magnitudes, he is aware that: (1) the alternatives are similar (at least on a gross basis), (2) the trade-offs are difficult and diverse among alternatives, and (3) the quantifiable costs and benefits may bear more heavily on the choice. Also, if a ratio of plus ratings is greater than .50 and the average rating is negative, it is known that there is a conflict in results. Again, a difficult trade-off situation is indicated.

8. The rating system, therefore, like its companion check list, is meant to be a flexible tool of evaluation. It is not meant as a standard or directive but as a guide to systematic analysis.

B. Soil Conservation Service (9)

1. The SCS method consists basically of an assessment of the environmental impacts of proposed actions on the physical environment.

2. Figure 14 shows the environmental diagram, with the basic divisions including land quantity and quality, water quantity and quality, and air quality.

3. Each item in the environmental diagram is specified as to the units of measurement. After each item is described in terms of the present condition, future condition, and the condition resulting from each alternative, various resource uses are examined

Figure 14

ENVIRONMENTAL DIAGRAM

RESOURCE

Indicators

			Cropland
			Pastureland
			Rangeland
			Recreation land
			Urban land
			Wildlife land
			Woodland
			Other

PHYSICAL ENVIRONMENT

LAND — Quantity

Quality
- Erosion, kind and degree
- Flood hazard, depth and frequency
- Deposition, amount and frequency

WATER — Quantity
- Lakes and ponds
- Storage
- Streams
- Streambank
- Minimum flow
- Ground water
  - Storage
  - Estimated life

Quality
- Nitrogen compounds
- Phosphorus
- Electrical conductance
- Toxic chemicals
- Total coliforms
- BOD
- COD
- Dissolved oxygen
- ph
- Temperature
- Sediment
- Turbidity
- Dissolved solids
- Odor intensity index

AIR — Quality
- Particulate matter
  - Pollen peak season
  - Pollen, count
  - Smoke, fly ash
  - Other dust and particulates
- Polluting gases
  - Carbon monoxide
  - Nitric oxide
  - Ozone
  - Sulfur dioxides
  - Ammonia
- Odor
- Patterns of movement
  - Inversions
  - Frost pockets
- Noise
  - Spectrum
  - Intensity

-56-

examples of resource uses include irrigation water, cropland
production, fish habitat, recreation, etc. Each resource use
is then evaluated by a specialist and an interdisciplinary tea ,
and assigned scaled ratings of 1 to 5 on the following basis

    1 = unsuited

    2 = poor

    3 = fair or neutral

    4 = good

    5 = excellent

4. Example of use of system

    a   The Saconv Creek Watershed is located in southeastern Penn-
        sylvania. The watershed needs include flood control, water
        for water supply and water quality, and water-based recrea-
        tion   A map of the watershed is in Figure 15

    b   Three alternative plans

    Alternative 1

    (1) Land treatment

    (2) Site 2 (multiple purpose flood prevention - Fish and
         Wildlife).

    (3) Channel improvement (60 ft. wide, 7,000 ft long) throug
         Kutztown (Normal Avenue to sewage treatment plant).

    Alternative 2

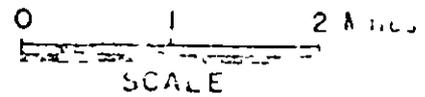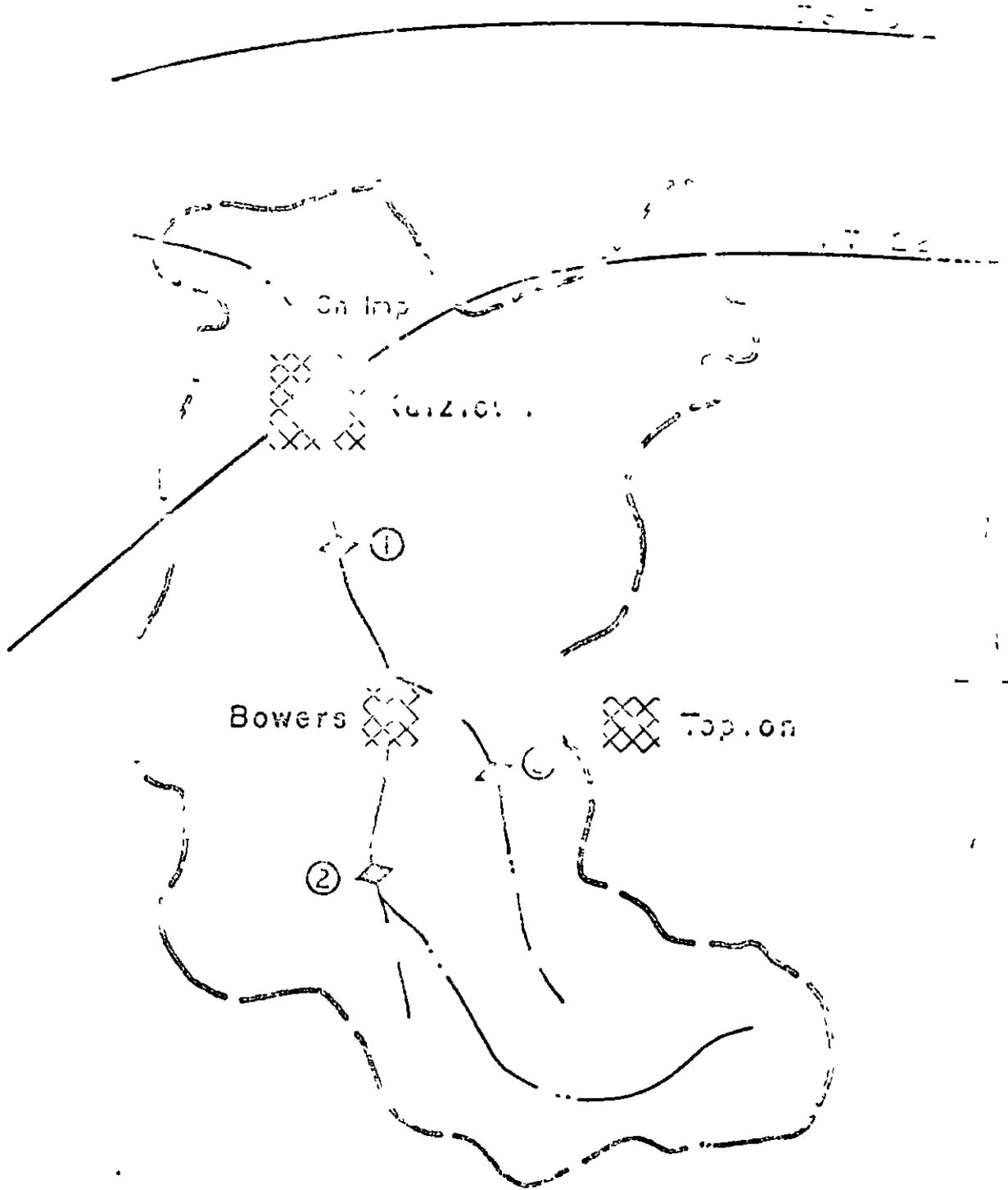   (1) Land treatment

    (2) Site 2 (multiple purpose as in alternative 1)

    (3) Site 3 (single purpose flood prevention)

    (4) Channel improvement (60 ft. wide, 6,000 ft long) throug
         Kutztown (Main Street to sewage treatment plant)

Figure 15

SACONY CREEK WATERSHED

Ch Inp

Kutztown

①

Bowers ⚔ ⚔ Topton

② ◇

Alternative 3

    (1) Land treatment

    (2) Site 3 (single purpose, flood prevention)

    (3) channel improvement (0 ft. wide, 5,500 ft. long), through Anytown (i.e. Select to sewage treatment)

   c. Table 9 shows the resource use analysis for rural & partial industrial water, and Table 10 is for recreation

   d. Table 11 shows the summary analysis

V. Examples of Scaling-Weighting Checklists

  A. Battelle's Environmental Evaluation System (10)

    1 Oriented to water resources development projects

    2 System Characteristics (See Figure 16)

      a Hierarchial -- accounts for levels of information

        general -- Environmental Categories (4)

        intermediate -- environmental components (17)

        specific -- environmental parameters (78)

      b Measures impact in commensurate units

      c. Alert system (red flags --- major and minor)

        sensitive areas

        data need

    3 Commensurate Units

      a Needed due to variety of units of expression for 78 environmental parameters

      b Steps

        (1) transform parameter estimates into environmental quality (EQ)

        (2) assign importance weights to parameters (PIU)

Table 9

RESOURCE USE
for

Municipal and Industrial Water

Description of area Sacony Creek Watershed and Borough of Topton

Berks County, Pennsylvania

Factors	Unit	Present	Future Without action	Alternative 1	Alternative 2	Alternative 3
Kutztown						
Supply						
Needed	mgd	0 53	0 99	0 99	0.99	0 99
Available	mgd	4 18	4.18	4 18	4 18	4 18
Storage						
Needed	m3	1 75	1 80	1 80	1 80	1 80
Available	mg	1 75	1.75	1.75	1 75	1 75
Quality		adequate treatment				
Water reuse	mgd	0				•
Kutztown--Spec	rating	5	4	4	4	4
Lyons and Bowers						
Supply						
Needed	mgd	042	075	.075	.075	075
Available	mgd	063	063	063	.063	.063
Storage						
Needed	mg	05	24	.24	.24	24
Available	mg	05	05	05	05	05
Quality		adequate treatment				
Water reuse	mgd	0				
Lyons and Bowers--Spec	rating	5	2	2	2	2
Topton						
Supply						
Needed	mgd	0 15	0 28	0 28	0 28	0 28
Available	mgd	0 15	0 15	0 15	0 15	0 15
Storage						
Needed	mg	29	.45	45	45	.45
Available	mg	29	29	29	.29	29
Quality		adequate treatment				
Water reuse	mpd	0				
Topton--Spec	rating	5	1	1	1	1
Industrial primary	rating	5	2	2	2	2
industrial primary with standby	rating	5	2	2	2	2

Table 10

RESOURCE USE
for

Recreation

Description of area: Sacony Creek Watershed, Region II, Great Valley Area,

Berks, Lehigh and Northampton Counties

Factors	Unit	Present	Future Without action	Alternative 1	Alternative 2	Alternative 3
Population in local area, of influence (LAI)	no.	616,000	632,000	632,000	632,000	632,000
Recreation land						
Quantity in LAI	acres	30,443	41,000	41,000	41,000	41,000
Quantity per 1,000 pop.	acres	49.4	64.9	64.9	64.9	64.9
Quantity in watershed	acres	40	60	95	95	60
Quality						
Adequate	acres	30	40	90	90	55
Not adequate	acres	10	20	5	5	5
Proximity	rating	4	5	5	5	5
Access	rating	4	5	5	5	5
Hunting land	acres	11,835	11,800	11,800	11,800	11,800
Recreation facilities and development	rating	4	4	4	4	4
Recreation water						
Quantity in LAI	acres	3,580	6,300	6,345	6,349	6,300
Quantity per 1,000 pop.	acres	5.8	10.0	10.0	10.0	10.0
Quantity in watershed	acres	40	45	90	94	45
Quality in watershed	rating	4	4	4	4	4
Fishing water, stream	miles	13.4	13.4	12.8	12.8	1.
Fishing water ponds	acres	40	45	90	94	4.

Description of area: Sacony Creek Watershed, Region II, Great Valley Area,

Berks, Lehigh and Northampton Counties

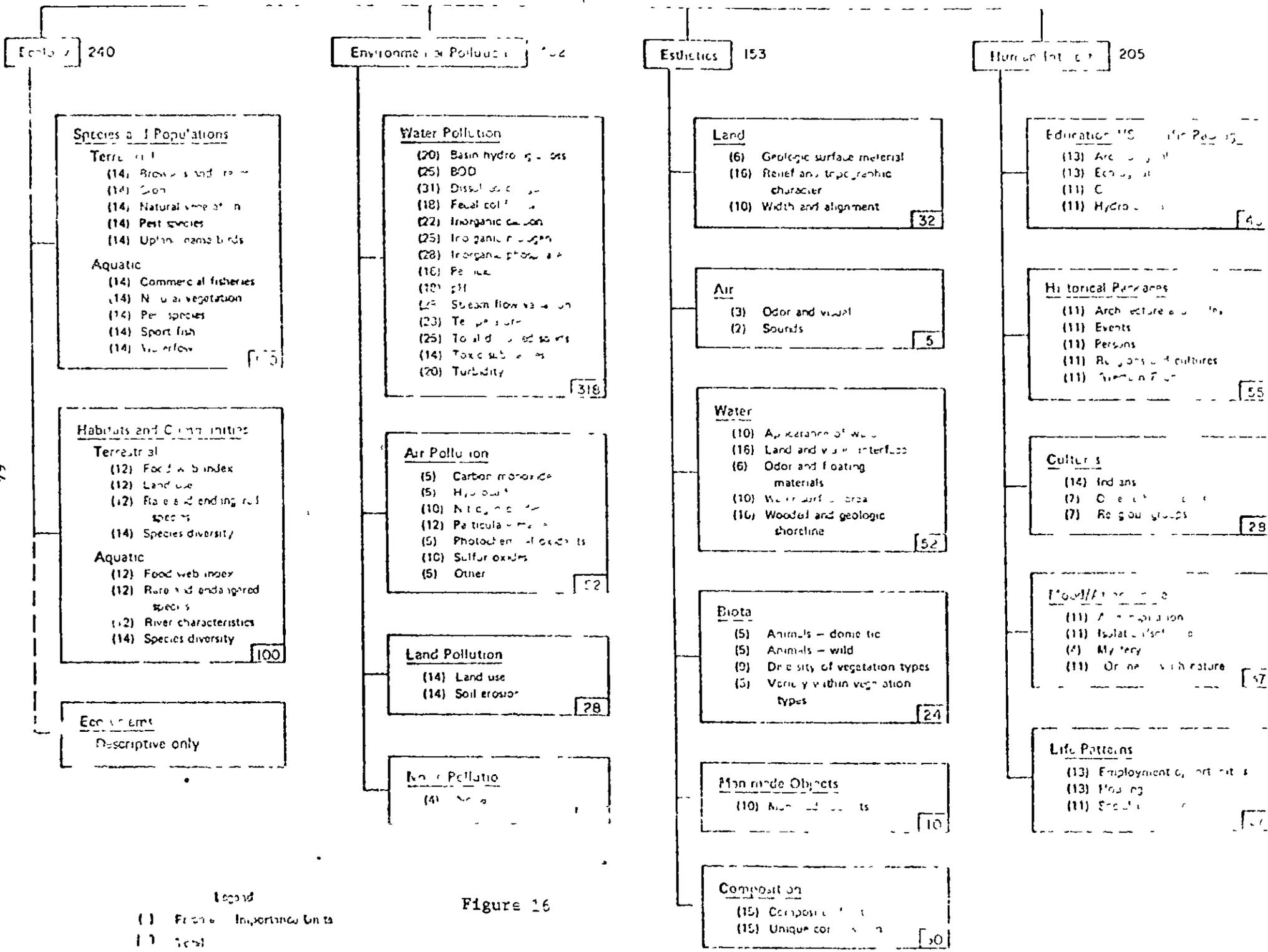| Factors	Unit	Present	Future Without action	Alter- native 1	Alter- native 2	Alter- native 3
Local area of influence recreation visits per yr.[1]						
Camping	supply/ demand	350/1,047	438/1,075			
Picnicking	supply/ demand	7,770/1,971	7,770/2,022			
Boating	supply/ demand	93/1,293	177/1,327	179/1,327	179/1,237	177/1,327
Swimming	supply/ demand	2,000/6,776	2,500/6,952			
Fishing	supply/ demand	268/1,355	472/1,390	476/1,390	476/1,390	472/1,390
Hunting	supply/ demand	1,044/492	1,044/560			
Total s	supply/ demand	11,525/ 12,934	12/,01/ 13,271			
Total opportunity	supply/ demand	361/2,648	649/2,717	655/2,717	655/2,717	649/2,717
Opportunity index supply divided by demand	pct	13 6	23.9	24.1	24.1	23.9
Specialist summary	rating	3	4	4	4	4
Interdisciplinary team summary	rating	2	3	3	3	3

1/ In thousands.

Table 11

Description of area Sacony Creek Watershed, Berks County, Pennsylvania

Resource Use		Present	Without action	Future Alternative 1	Alternative 2	Alternative 3
Cropland production	– Specialist	2	3	4	–	4
	Team	3	3	4	4	4
Fish habitat	– Specialist	3	3	4	4	3
	Team	3	3	4	4	3
Irrigation water	– Specialist	3	3	4	4	4
	Team	3	3	4	4	4
Low flow	– Specialist	2	2	5	5	2
	Team	2	2	4	4	2
Mineral extraction	– Specialist	3	3	3	3	3
	Team	3	3	3	3	3
Municipal and industrial water supply	– Specialist	5	2	2	2	2
	Team	5	2	2	2	2
Pastureland production	– Specialist	2	3	4	4	4
	Team	2	3	4	4	4
Recreation	– Specialist	3	4	4	4	4
	Team	2	3	3	3	3
Wildlife	– Specialist	2	2	2	2	2
	Team	3	3	3	3	3
Woodland production	– Specialist	1	4	4	4	4
	Team	3	4	4	4	4
Economic national	– Specialist	3	3	4	4	4
	Team	2	2	4	4	4
Economic regional	– Specialist	3	3	4	4	4
	Team	3	3	4	4	3
Quality of landscape	– Specialist	3	3	3	3	3
	Team	3	3	3	3	3
Social	– Specialist	4	4	4	4	4
	Team	3	3	4	4	4
Unique cultural, and historical	– Specialist	4	4	4	4	4
	Team	4	4	4	4	4

Rating scale -- 1 unsuited, 2 poor, 3 fair or neutral, 4 good, and 5 excellent

Ecology 240

Species and Populations
Terrestrial
(14) Browsers and grazers
(14) Crops
(14) Natural vegetation
(14) Pest species
(14) Upland game birds

Aquatic
(14) Commercial fisheries
(14) Natural vegetation
(14) Pest species
(14) Sport fish
(14) Waterfowl
[75]

Habitats and Communities
Terrestrial
(12) Food web index
(12) Land use
(12) Rare and endangered species
(14) Species diversity

Aquatic
(12) Food web index
(12) Rare and endangered species
(12) River characteristics
(14) Species diversity
[100]

Ecosystems
Descriptive only

Environmental Pollution 402

Water Pollution
(20) Basin hydrologic loss
(25) BOD
(31) Dissolved oxygen
(18) Fecal coliforms
(22) Inorganic carbon
(25) Inorganic nitrogen
(28) Inorganic phosphate
(16) Pesticides
(18) pH
(28) Stream flow variation
(28) Temperature
(25) Total dissolved solids
(14) Toxic substances
(20) Turbidity
[318]

Air Pollution
(5) Carbon monoxide
(5) Hydrocarbons
(10) Nitrogen oxides
(12) Particulate matter
(5) Photochemical oxidants
(10) Sulfur oxides
(5) Other
[52]

Land Pollution
(14) Land use
(14) Soil erosion
[28]

Noise Pollution
(4) Noise

Esthetics 153

Land
(6) Geologic surface material
(16) Relief and topographic character
(10) Width and alignment
[32]

Air
(3) Odor and visual
(2) Sounds
[5]

Water
(10) Appearance of water
(16) Land and water interface
(6) Odor and floating materials
(10) Water surface area
(10) Wooded and geologic shoreline
[52]

Biota
(5) Animals — domestic
(5) Animals — wild
(9) Diversity of vegetation types
(5) Variety within vegetation types
[24]

Man-made Objects
(10) Man-made objects
[10]

Composition
(15) Composite effect
(15) Unique composition
[30]

Human Interest 205

Education/Scientific Packages
(13) Archeological
(13) Ecological
(11) Geological
(11) Hydrological
[48]

Historical Packages
(11) Architecture and styles
(11) Events
(11) Persons
(11) Religions and cultures
(11) Western Frontier
[55]

Cultures
(14) Indians
(7) Other ethnic groups
(7) Religious groups
[29]

Mood/Atmosphere
(11) Awe/inspiration
(11) Isolation/solitude
(4) Mystery
(11) Oneness with nature
[37]

Life Patterns
(13) Employment opportunities
(13) Housing
(11) Social interactions
[37]

Figure 16

c. multiply EQ x PIU to obtain environmental impact unit (EIU)

   EIU = EQ x PIU

3. LQ

   a. values from 0 to 1

   b. 0 = extremely bad quality

   c. 1 = very good quality

   d. range of values

   e. provides common bases

   f. value function based data and/or judgment

   g. see Figures 17-20 for examples

4. PIU

   a. 1,000 PIU divided among categories, components, parameters

   b. "ranked pairwise comparisons"

   c. example of ranked pairwise comparison: Distribution of 100
      PIU among 3 water pollution parameters: Turbidity (2), D.O.
      (1), Chlorides (3)

      Assign to DO value of   1.5
      Turbidity = ½ of D.O. =   0.5
      Chlorides = 1/5 of
                  Turbidity =   0.1
                              ──────
                                1.6

      $DO = \frac{1.0}{1.6} (100) = 63$

      $Turbidity = \frac{0.5}{1.6} (100) = 31$

      $Chlorides = \frac{0.1}{1.6} (100) = 6$

   d. see Figure 16 for results

5. Steps in Using Environmental Evaluation System
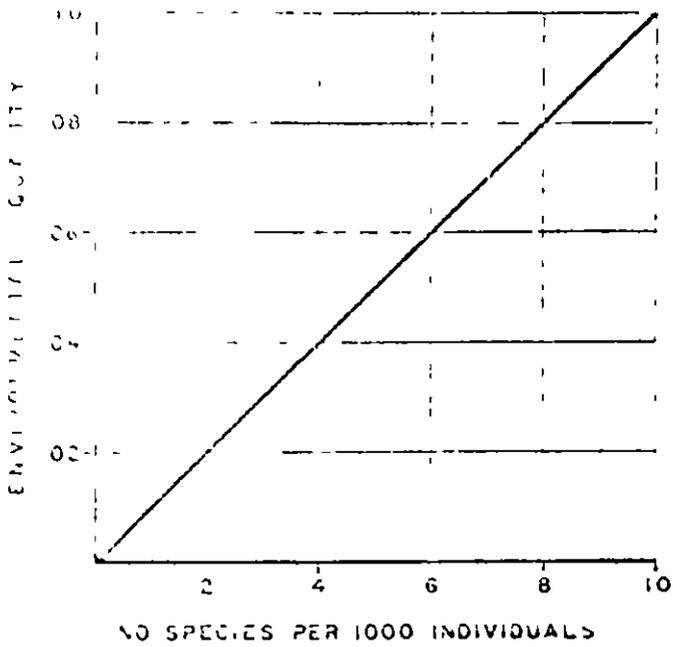
FIGURE 17 SPECIES DIVERSITY
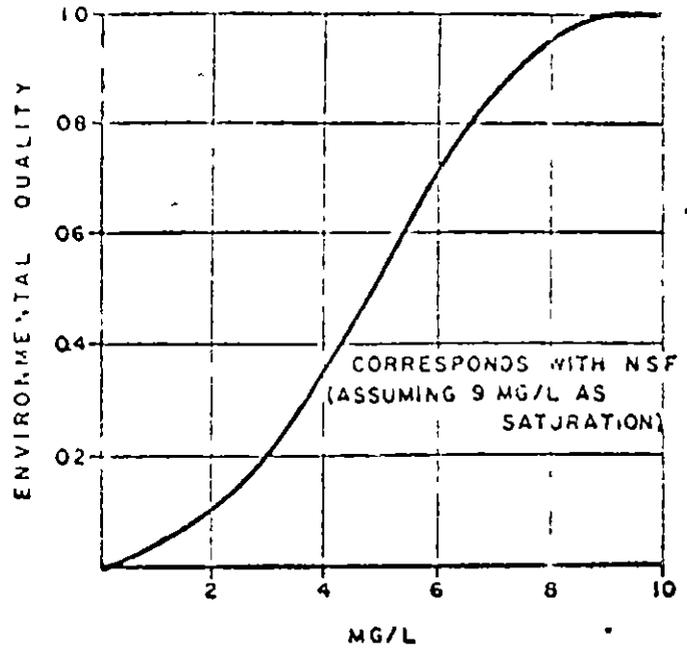
FIGURE 18 DISSOLVED OXYGEN
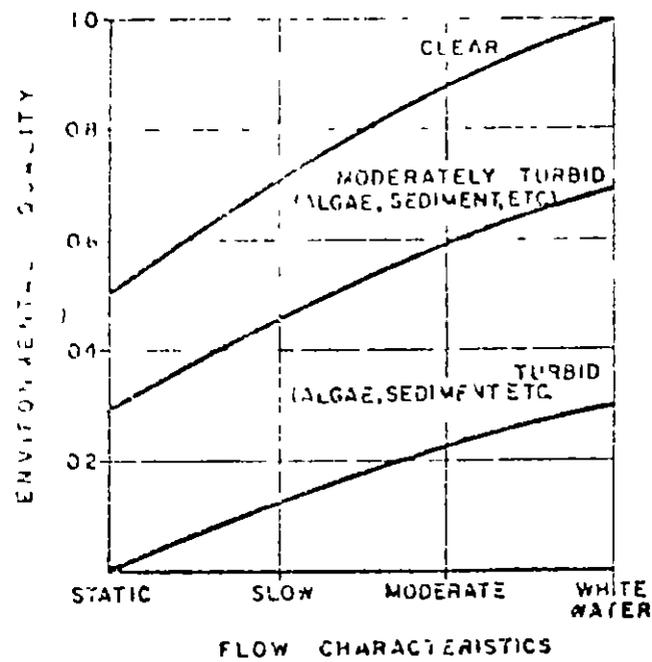
FIGURE 19 APPEARANCE OF WATER
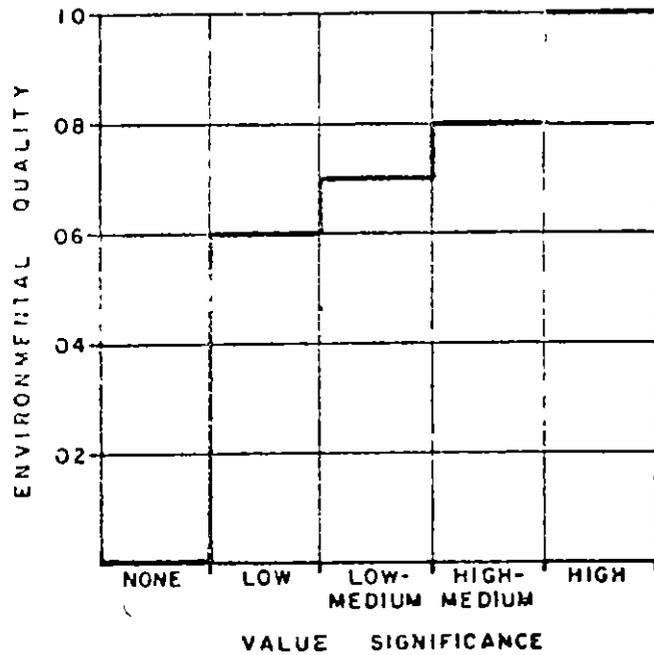
FIGURE 20. HISTORICAL EXTERNAL PACKAGES

-66-

a. Define boundaries of the project, in terms of area and time

b. Obtain parameter data without the project, and develop or predict the data with the project.

c. Determine EIU, without and with the project.

d. Determine "red flags"

e. Report information in summary, can see trade-offs.

B. Evaluation of Battelle Environmental Evaluation System

1 Highly organized. Helps to insure a systematic (all-inclusive) approach, and identify critical changes.

2 Does not include enough emphasis on socio-economic factors.

3. Needs built-in flexibility for adding new parameters and adapting PIU to projects.

4. Needs more development of parameter function graphs.

5. Need more details on evaluation during construction and operational phases, and also for various spatial boundaries.

6. Specific system would have to be modified in order to apply it to non water-resources projects.

7. Very good in showing trade-offs within a component, within a category, or between categories. For example.

CATEGORY	ALT. A (no action)	B	C
(240) Ecology	215	200	220
(402) Inv. Pollution	340	350	310
(153) Esthetics	110	120	135
(205) Human Interest	180	175	175

8 There is no passing or failing "score"; these must be subjected to professional interpretation.

C. Uses of Battelle Approach

-67-

1   Proposed Aubrey Lake in North Texas (11)

2   Rapid transit system in Atlanta (12)

D   Odum's Optimum Pathway Matrix (13)

   1. Background of study

      a. Time for decision

      b. 8 alternatives for completion of a section of I-75 north of Atlanta. See map.

      c. route F recommended by Ga Highway Dept. w/o detailed consideration of environment

      d. use available data, recommendation for additional study is not legitimate.

      e. done in 3 weeks

   2. Considered McHarg method

      a. gross screening

      b. not specific enough for final selection of this case

      c. graphical presentation of environmental characteristics

   3   Identified 56 factors (component values) and grouped them into

   Group E   Economic and Highway Engineering

          L   Environmental and Land Use Considerations

          R   Recreation Considerations (due to importance of Allatoona Lake in Atlanta area)

          S   Social and Human Considerations

   Some factors identified with more than one group. See App. 1

   4   Assemble data on each of the 56 factors

   5   Unitize data for each factor with the largest value for a factor = 1
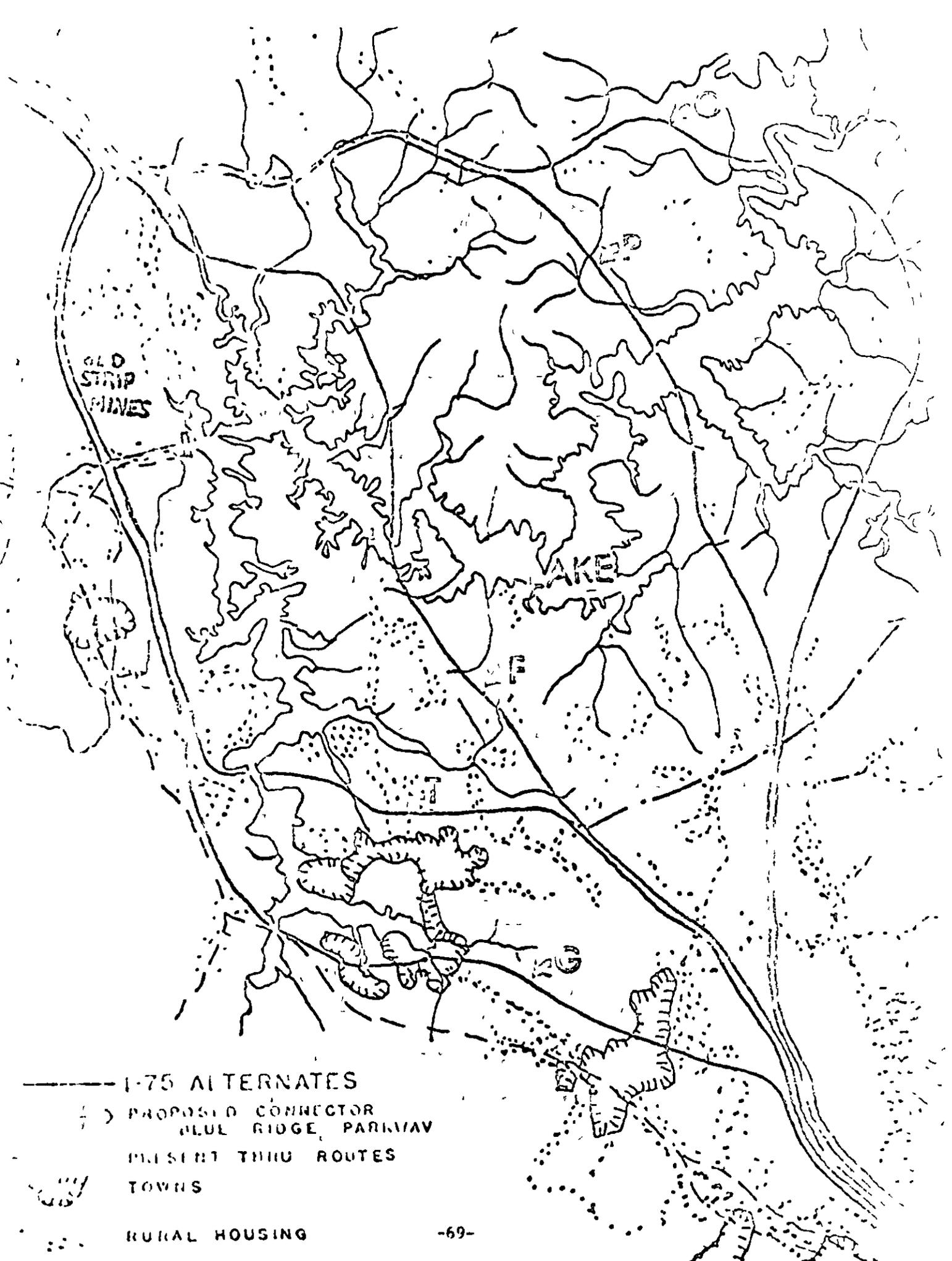
OLD
STRIP
MINES

LAKE

F

--------- I-75 ALTERNATES

PROPOSED CONNECTOR
BLUE RIDGE PARKWAY

PRESENT THRU ROUTES

TOWNS

RURAL HOUSING

-69-

c	Component		Total		Location	C	G-1	T	T-1	-1	b	G
			Initial	Term								
	Land Remove for R O W (Acres)											
1	Pine		- 3	-10	L	1407	1411	1438	1442	1352	1356	841	825
2	d		- 4	-10	L	1619	1619	1406	1406	1092	1092	1263	1445
3	Hardwood		- 7	-10	L	215	226	277	268	344	355	157	164
4	Agricultural		- 3	-10	L	313	282	305	275	325	294	257	279
5	Idle		+ 5	+ 8	L	227	237	175	185	147	157	61	51
6	Water		- 7	- 4	L	17	27	23	33	22	32	52	19
7	Swamp		- 4	- 4	L	0	0	0	0	0	0	0	2
8	Mired Land		+ 8	+10	L	69	69	68	68	0	0	0	0
9	Urban		- 6	+10	L-S	212	199	175	156	68	40	22	30
10	Water Supplies Affected		- 2	0	L-S	1	1	1	1	0	0	0	0
11	Unique Areas		- 2	- 2	L-S	0	0	0	0	0	0	1	1
12	Streams Crossed		- 2	- 2	L	29	27	28	36	36	24	23	24
13	Small Bridgements		- 2	- 2	L	6	4	4	2	2	0	0	0
	Major Bridges											
14	Across Main Body	Number	- 5	- 5	L-R	0	0	0	0	1	1	1	0
15	of Lake	Length (ft)	- 5	- 5	L-R	0	0	0	0	1400	1400	3100	0
16	Across other than	Number	- 3	- 3	L-R	2	3	2	2	1	2	0	2
17	Main Body	Length (ft.)	- 3	- 3	L-R	1600	2100	1700	2300	500	1000	0	1500
18	Composite soil Li ons		- 4	- 3	I-C	293	293	300	300	320	320	328	303
19	Max Sediment Posi		- 6	- 3	L-E	315	313	295	292	350	397	270	290
20	Min Sediment Expected		- 8	- 3	L-E	44	44	40	40	48	48	37	40
21	Area to be Paved		- 2	- 2	L-E	75	666	649	640	553	644	519	609
	Area Affected by Noise (miles^2)											
22	Some		- 7	- 4	S-L	103	103	90	90	63	63	64	73
23	Great		- 7	- 7	S-L	33	33	50	50	84	84	95	66
24	Total System Cost ($x10^6)		-20	0	E	108	101	103	95	106	98	89	82
25	Annual Costs ($x10^6)		0	-20	E	8 7	8 3	8 5	7 8	8 6	8 0	7 2	6 8
26	Total Excavation/System (Yds x10^6)		- 2	0	I-L	25 3	25 0	25 5	25 3	20 6	20 1	20 9	25 5
27	Annual Road User Costs ($x10^6)		-10	-10	L-S	90 8	91 9	90 0	91 1	88 5	89 1	94 2	103 7
28	Benefit/Cost Ratio		-10	-10	E	- 17 1	- 9 6	- 9 8	- 3 2	0 0	- .9	- 4 1	- 8 2
29	Interstate Highway Mileage		- 2	- 2	S-E	27 1	27.1	27 1	27 1	24 5	24 5	27 4	31 9
30	Taxable Land Removed (Acres)		- 8	- 8	S-E	3955	3995	3737	3736	3039	3064	2557	2896
31	Public Land Removed (Acres)		- 8	- 8	S-E	242	197	200	204	401	338	151	92
32	Total Family Displacements		-20	0	S-E	177	99	177	97	146	66	101	53
	Nearby Residences Affected (Noise)											
33	Daytime Activity	(Some)	- 2	- 2	S	3072	3015	3227	3432	1555	1677	1956	2521
34	Disturbance	(Great)	- 5	- 5	S	789	797	2006	1901	1369	1076	993	9
35	Nighttime Sleep	(Some)	- 4	- 4	S	1431	1072	1165	876	954	519	637	5
36	Disturbance	(Great)	-10	-10	S	174	215	470	513	203	306	193	200
37	Churches Affected	(Some)	- 2	- 2	S	10	8	6	7	6	7	5	7
38	By Noise	(Great)	- 5	- 5	S	2	2	2	3	4	4	3	3
39	Schools Affected	(Some)	- 3	- 3	S	2	1	0	0	0	0	0	3

No.	Component	Relative Weights		Classi-fication	Routes							
		Initial	Long-Term		C	C-1	T	T-1		F-1	?	O
40	Py Noise (Great)	-10	-10	S	0	0	1	6	1	?	1	0
	Livestock ...						3			82	5	5
41	Short Term (1981)	+50	0	S-E	16	16	42	42	82	82	5	5
42	Long Term (1993)	0	+50	S-E	377	377	389	389	385	385	351	355
43	Number Interchanges	+ 2	+ 6	S-E	16	16	14	14	13	13	10	10
	Secondary Growth Impact										4	6
44	Potential for Development	0	+25	S-E	10	10	10	10	8	8	4	6
45	Suitability for Development	0	+25	S-E	+ 8	+ 9	+ 8	+ 9	- 7	- 6	- 9	- 5
46	Water Quality	5	2	R-S	- 1	- 3	- 1	- 2	- 2	- 3	- 2	- 2
47	Visual Disturbance	2	2	R	- 2	- 3	- 2	- 3	- 5	- 6	- 5	- 2
48	Hunting and Game	4	1	R	0	- 1	- 0	- 1	- 6	- 7	- 6	- 4
49	Natural Character Loss	4	4	R-S	- 1	- 2	- 1	- 2	- 4	- 5	- 3	- 2
50	Safe Access	6	6	R-S-E	+ 6	+ 7	+ 6	+ 7	+ 6	+ 7	+ 4	+ 2
51	Impact on Planned Reservoir Use Pattern	1	2	R-S-L	+ 2	+ 3	+ 2	+ 3	+ 3	+ 4	- 2	- 3
52	Driving for Pleasure	2	1	R-S	+ 3	+ 4	+ 3	+ 4	+ 8	+ 9	+ 8	+ 7
	Composite Noise Effect											
53	Camping	- 3	- 3	R	44	44	- 48	- 48	89	89	51	23
54	Picnic	- 2	- 2	R	40	40	87	87	26	26	17	9
	Recreational Land Loss											
55	Present	5	0	R	3	- 4	- 1	- 2	- 6	- 7	- 4	- 3
56	Potential	0	3	R	1	- 2	- 1	- 2	- 4	- 5	- 5	- 3

a   define scaling factor

$$Sx = \frac{1}{\text{max. of } X_1, X_2, \text{----}, X_8}$$

b.   example

(Factor 9) $S_9 = \frac{1}{212}$

Unitized values.

Route G $= \frac{212}{212} = 1$

T $= \frac{175}{212} = 0.825$

F $= \frac{68}{212} = 0.321$

etc.

c   linear scaling

d. dimensionless numbers for comparison

6. Group decision on relative weights of initial and long-term effects

a   range of -20 to +50

(-50)

b   long-term effects considered to be 10 times greater than initial

(10 - 20 yr period)

c   example

Composite weighting value for Factor 1 = W_1

W_1 = (-3) (1) + (-10) (10) = -103

W_2 = (-6) (1) + (+10) (10) = +94

7. Unitize weighting values by dividing each weight by the total sum

of all weights

Ni = unitized weighting value

$$= \frac{W_1}{\Sigma,^{56}W_1} \, ,$$

8. Calculate an environmental index for each route

I_{Route} = environmental index

$I_{Route} = \Sigma^{56}, \, N_1 \, Sx_i \, X_i \pm (e) \, N_1 \, Sx_i \, X_i$

9. X_i = component value

   Sx_i = scaling factor

   N_i = unitized weighting value

   e = error term to allow for misjudgment on relative weights

      by $\pm$ 50% stochastically selected.

9. Calculate I_{Route} 20 times for each route through computer program.

   a. mean

   b. standard deviation

      See App. 2

10. Results
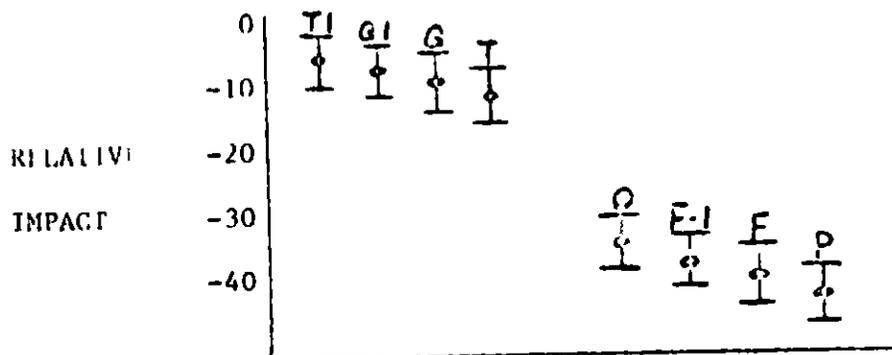
11 Computer analysis allow consideration of many sub-groups

   a   E, L, R, S or combination

   b   equal weight to initial and long-term effects

   c. etc.

12. Route T was recommended

Appendix 2. Results of 20 stochastic runs for each of 8 alternates. Mean impact
index, standard deviation and 95% confidence interval are shown for
each route.

ROUTE G

RESULTANT VALUE

PASS 1	-20.815
PASS 2	- 6.738
PASS 3	- 1.986
PASS 4	-15 550
PASS 5	- 7 423
PASS 6	- 8.737
PASS 7	-12.596
PASS 8	- 5.359
PASS 9	-12.800
PASS 10	- 8.908
PASS 11	- 4.012
PASS 12	- 8.064
PASS 13	-12.650
PASS 14	- 8.472
PASS 15	- 4.082
PASS 16	- 8.584
PASS 17	- 3 563
PASS 18	- 3.817
PASS 19	-13.681
PASS 20	-11.035

MEAN . . . . - 8.944

STANDARD DEVIATION   4.736

95% CONFIDENCE INTERVAL FROM -11.160 to -6 727

E. Other Examples

    1. Stover (14)

    2   Bureau of Reclamation (15)

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PREDICTION AND ASSESSMENT OF IMPACTS

ON THE WATER ENVIRONMENT

I. Introduction

    A. Examples of projects causing water quality impacts

        1. <u>Construction</u> of reservoirs, power plants, industrial parks and pipelines.

        2. <u>Operation</u> of sewage treatment plants, reservoirs, industrial parks and power plants.

    B. Basic steps in prediction and assessment of water quality impacts.

        1. Identify the types of water pollutants emitted from the alter-natives for a given project need during both construction and operational phases. This may involve a literature review or analysis of other EIS's on same types of alternatives. It is desirable to assemble "unit waste generation" figures, and use these to eventually determine the total point and non-point source waste loads.

        2. Determine the existing water quantities and quality levels for the surface water courses in the area. Examine the frequency distributions, median and mean data for both water quality and quantity. If possible, consider historical trends of water

---

quality information. Note 7-day, 10-year low flow.

3. Note any unique pollution problems which have occurred in the
    surface watercourses of the area.--For example, fish kills,
    algae growth or thermal discharges causing stratified flow.

4. Describe the groundwater quantity and quality in the area,
    noting particularly the depth to the groundwater table and the
    direction of flow. Identify major uses of groundwater in the
    area,_and any historical trends,in terms of groundwater
    depletion.

5. Assemble summary_of key meteorological parameters in the area,
    noting particularly the monthly records of precipitation, evap-
    oration and temperature.

6. Procure applicable water quality standards.

    (a) effluent standards and required treatment technologies

    (b) water quality or in-stream standards

    (c) determine the "controlling" standard

    (d) time schedule required for meeting the standards

7. Summarize the waste load allocation study for the area. Iden-
    tify the known point sources of pollution, noting particularly
    any unique discharges or constituents. Also identify the
    quantity and types of water uses in the area.

8. Determine the mesoscale impact by calculating the estimated
    daily quantities of water pollutants from the project (alterna-
    tives) during both the construction and operational phases.
    Determine the percentage increase in the waste loads to the
    stream.

2

9. Discuss the construction phase impacts in terms of the following:

(a) time period of construction and the resultant time period of decreased water quality. Note the stream discharges during the construction phase, and also the quality variations.

(b) the anticipated distance downstream of decreased water quality; since sediment is the major concern, could perhaps apply "dilution" model or "sedimentation" model to predict stress levels of suspended solids.

(c) discuss the implications of any decreased water quality in terms of area water users. Show the raw water quality requirements for various area water users.

(d) refer to any specific construction specifications directed toward pollutant minimization.

10. Determine the microscale impacts by calculating specific downstream concentrations of conservative pollutants, or dissolved oxygen concentrations resulting from non-conservative (organic) pollutants, or downstream termperatures resulting from thermal discharges. Consider these microscale impacts for both the construction and operational phases. Compare the calculated levels with applicable water quality standards. Check also to see if applicable effluent standards are met.

11. If water quality or effluent standards are exceeded, consider mitigation or control measures. One possibility is pollutant minimization through wastewater treatment and/or volume reduction.

228

12. Discuss the <u>operational</u> impacts in terms of the following

    (a) frequency distribution of decreased quality or quantity.

    (b) die-away pattern of pathogenic organisms.

    (c) effects of sedimentation on stream bottom ecosystem.

    (d) fate of nutrients by incorporation into biomass.

    (e) reconcentration of metals, pesticides or radionuclides into the food web.

    (f) chemical precipitation or oxidation/reduction of inorganic chemicals.

    (g) the anticipated distance downstream of decreased water quality, and the implications in terms of area water users.

    (h) effects of any water quality changes on stream ecosystem.

    (i) unique quality changes which occur as a result of water impoundment.

II. Basic Information on Water Pollution

    A. Definition of Water Pollution

        1. Resources out of place.

        2. Ecosystem overload.

        3. Basic structure of definition involves quantity or concentration of material in water for a sufficient time or duration to cause certain effects. The effects can be health-related (contamination), impose limitations on water use (pollution, or be aesthetically displeasing (nuisance).

    B. Water Quality Characterization

1. Need --- Wastewaters and receiving waters are normally charact-
   erized in terms of their physical, chemical, and biological
   quality or character. It is not sufficient to evaluate waste-
   water or receiving water in terms of only one of these classi-
   fications. The final or total evaluation depends on the
   rational, integrated evaluation of the characteristics in
   terms of the previously mentioned classifications.

2. Physical parameters

   (a) color --- type of color (true or apparent), and density of
       color.

   (b) odor --- type of odor, and threshold odor number

   (c) temperature

   (d) solids --- total solids, light transmittance (turbidity),
       settleable solids, suspended and dissolved solids, organic
       (volatile) and inorganic (fixed) solids, and specific
       conductance (conductivity).

   (e) oil and grease

3. Organic parameters

   (a) biochemical oxygen demand (BOD) --- 5-day and ultimate. See Fig 1. (1)

   (b) chemical oxygen demand (COD)

   (c) BOD/COD relationship

   (d) total organic carbon (TOC)

   (e) total oxygen demand (TOD)

   (f) comparative analysis of organic parameters

4. Inorganic parameters

   (a) salinity

-5-
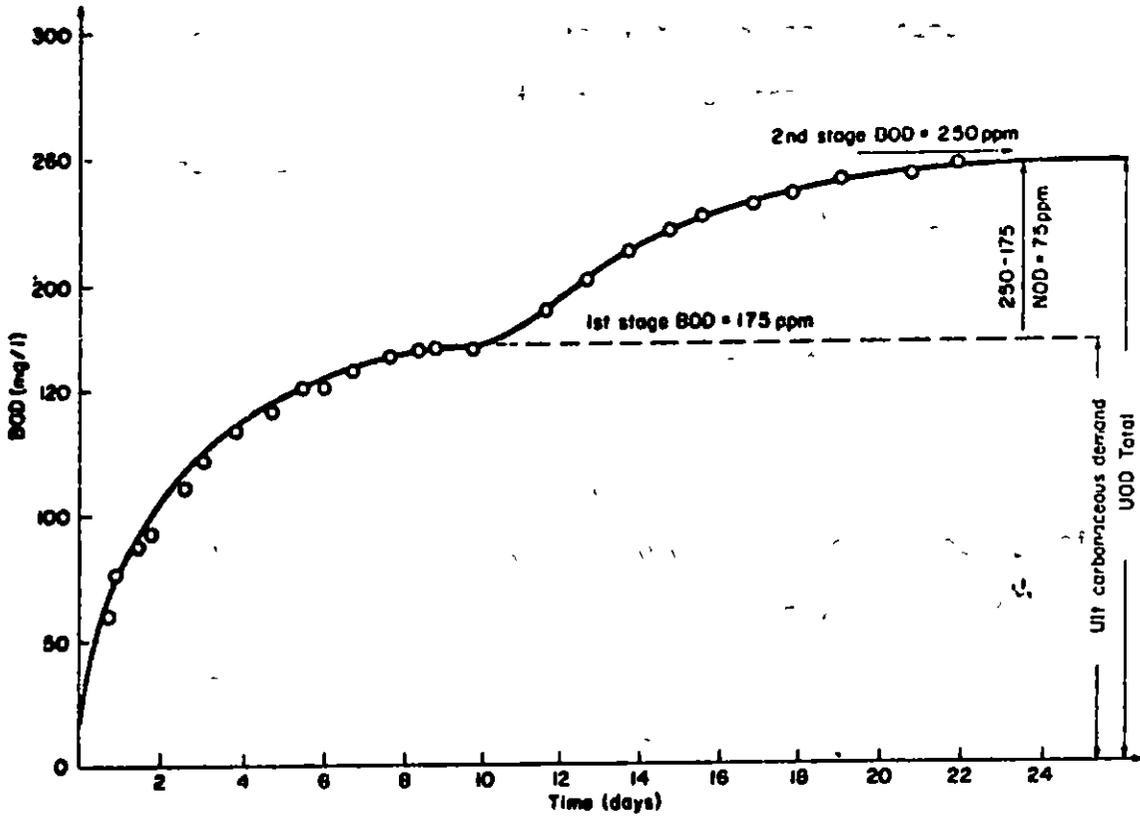
FIG. 3   BOD versus time for Brookside sewage 4-1-65 to 4-23-65 at 20°C

-6-

(b) hardness

(c) iron and manganese

(d) pH, acidity, and alkalinity

(e) chlorides

(f) sulfates and sulfides

(g) heavy metals (Hg, Pb, Cr, Cu, Zn, others)

(h) nitrogen (organic, ammonia, nitrite, nitrate)

(i) phosphorus

5. Bacteriological parameters

(a) coliforms

(b) fecal coliforms

(c) specific pathogens

(d) viruses

6. Bioassay tests for toxicity

III. Sources of Water pollution

The sources of pollutants in aqueous sytems are manifold, and the re-
sultant deterioration of water quality may or may not be attributable to
single pollutants or single sources. This discussion will be directed to-
ward an examination of the major sources of water pollution; including
municipalities, industries, agriculture, soil erosion, oil and other
hazardous substances, mine drainage and watercraft wastes.

A. Municpal Wastes (2)

1. Municipal discharges and industries discharges are the two
   major water pollutant sources in the United States.

2. Magnitude of municipal discharges:

(a) 32% of the U.S. population have no sanitary sewers

(b) of the 68% with sewers; 40% have adequate sewage treatment, 46% have inadequate sewage treatment, and 14% have no treatment at all.

(c) therefore, less than one-third of the nation's population is served with adequate sewers and sewage treatment.

(d) average sewage flow is 100 gallons per person per day.

3. On a nationwide average, about 45% of the wastes processed in municipal plants are from industries.

4. Waste loads from municipalities are expected to quadruple in the next 50 years.

5. Over 1,000 communities outgrow their treatment facilities each year.

6. Storm sewers or combined sewers contain variety of wastes washed from streets.

B. Industrial Wastes (2)

1. There are more than 300,000 water-using factories in the United States.

2. The growth rate of industrial wastewater discharges is greater than that from municipal discharges.

3. Industrial wastes can be categorized according to several bases, for example, those industries having high BOD wastes, high suspended solids, etc.

4. The quality characteristics of industrial wastewaters vary considerably.

5. Population equivalent $= \dfrac{A \times B \times 8.34}{0.17}$

where A = industrial waste flow (mgd)

B = industrial waste BOD (mg/l)

C. Agricultural Wastes (2)

1. The two primary categories are irrigation return waters and runoff from feedlots.

2. Irrigation return waters

(a) comprise between 30 and 40% of total U.S. water usage of about 400 bgd.

(b) salinity increases several-fold; also hardness, total dissolved solids, and turbidity.

(c) may exhibit increases in nitrogen and phosphorus

(d) may contain pesticides

3. Runoff from feedlots

(a) Animal wastes are estimated to be the equivalent of the wastes of 2 billion people. These figures should not be interpreted as an estimate of the potential pollution from feedlots, however, since most of these wastes never reach water. However, they are a measure of the total amount of animal wastes, part of which causes water pollution and solid waste problems.

(b) On the basis of the 5-day BOD, a feedlot with 10,000 cattle is equivalent to a city of about 45,000 people.

(c) contains nutrients

(d) contains solids and organics

(e) contains microorganisms that are pathogenic to animals and to man

-8- 4.1

D. Soil Erosion (2)

1. Greatest volume of wastes entering the surface waters of the U.S. comes from sediment resulting from soil erosion.

2. Volume of solids from soil erosion is some 700 times greater than the total sewage discharge loadings.

3. Sediment from soil erosion is greatest in streams in the southwest and far west; for example, in the states of Nevada, Arizona, New Mexico, Texas, Oklahoma, Kansas, etc.

4. Adds turbidity and discoloration to receiving streams.

E. Oil and Other Hazardous Substances (2)

1. Accidental and intentional dumping of oil and other hazardous substances into watercourses is of fairly recent interest.

2. Two recent events:

    (a) 1967 -- grounding of "Torrey Canyon"

    (b) 1969 -- Santa Barbara offshore oil leak

3. Two-thirds of the oil spills exceeding 100 barrels come from vessels; the rest comes from pipelines, oil terminals and bulk storage facilities.

4. In 1968 there were 714 reported oil spills (over 100 barrels) in U.S. waters; in 1969 there were 1,007.

5. Many other hazardous materials could be spilled; examples include cyanide, clorine, etc.

6. Damage to aqueous environment can be devastating and extensive.

F. Mine Drainage (2)

1. Important in mining areas of the U.S., particularly in Appalachia and the Ohio Basin States. (estimated 75% in these areas)

2. Acid mine drainage has deteriorated water quality levels below desirable limits along 10,500 miles of streams in Appalachia.

3. Acid formation occurs when water and air react with the sulfur-bearing minerals in the mines or refuse piles to form sulfuric acid and iron compounds.

4. Mine drainage also contains copper, lead, zinc and other metals toxic to aquatic life

5. Another area of concern is the sediment yields from strip mining operations. About 150,000 acres per year is disturbed by surface mining operations, sediment yields from strip mine areas may be as large as 30,000 tons/sq. mile/yr.

G. Watercraft Wastes *(C)*

1. Over 8 million watercraft navigate U.S. waters, and they discharge sanitary waste, oil, litter, and ballast and bilge waters.

2. Most of the discharges are in shoreline and harbor areas.

IV. Effects of Pollutants on Receiving Waters

A. Soluble Organics

1. Depletion of oxygen --- sag equations

2. Biomagnification --- pesticides in oysters

3. Trace quantities --- taste and odors (phenols)

B. Suspended Solids

1. Decrease clarity --- perhaps hinder photosynthesis

2. Sludge deposits --- change in bottom ecosystem

C. Color, Turbidity, Oils and Floting Materials

1. Decrease clarity

2. Aesthetically displeasing

D. Nitrogen and Phosphorus

   1. Nutrients

   2. Algal growth and resultant decay may cause problems.

E. Chlorides --- salty taste.

F. Acids, Alkalies and Toxic Substances

   1. Cause imbalance in ecosystem.

   2. Fish kills

G. Heat

   1. Stratified flow

   2. Cause imbalance in ecosystem.

   3 Cause change in waste assimilative capacity

V. Identification of Water Pollutants (Step 1)

A. Definition of Pollutants (3)

   1. It's illegal under the 1972 Federal Water Pollution Control Act
to discharge pollutants into the Nation's waters except under
an NPDES permit.

   2. Pollutants covered by this permit requirement are. Solid waste,
incinerator residue, sewage, garbage, sewage sludge, munitions,
chemical wastes, biological materials, radioactive materials,
heat, wrecked or discarded equipment, rock, sand, collar dirt,
and industrial, municipal, and agricultural wastes discharged
into water.

   3. Excluded from the NPDES permit program are: Discharges of
sewage from vessels; pollutants from vessels or other floating

-11-

craft in coastal or ocean waters, discharges from properly

functioning marine engines, water, gas, or other material in-

jected into oil or gas wells, or disposed of in wells during

oil or gas production if the State determines that ground or

surface water resources will not be degraded; aquaculture

projects, separate storm sewer discharges; and dredged or fill

material.

4. Discharges excluded from the NPDES permit system are covered

by other pollution control requirements.

B. Categories of Sources

1. Point sources

2. Non-point sources

3. The total waste load to a stream is the sum of the point and

non-point sources of pollutants. The complete relationships

are shown in Figure 2. (4)

C. Some Examples of Waste Generation Figures

1. Sediment from non-point sources. See Tables 1 and 2, and Figure 3 (5)

2. Nutrients and BOD from non-point sources. See Table 3. (6)

3. Nutrients from non-point and point sources. See Table 4. (7)

4. Nutrients from agricultural sources. See Table 5. (8)

5. BOD from non-point and point sources. See Table 6. (9)

6. Quality of untreated domestic sewage point sources. See Table 7. (10)

7. Bacterial loadings from non-point and point sources. See Table 8. (11)

Figure 2
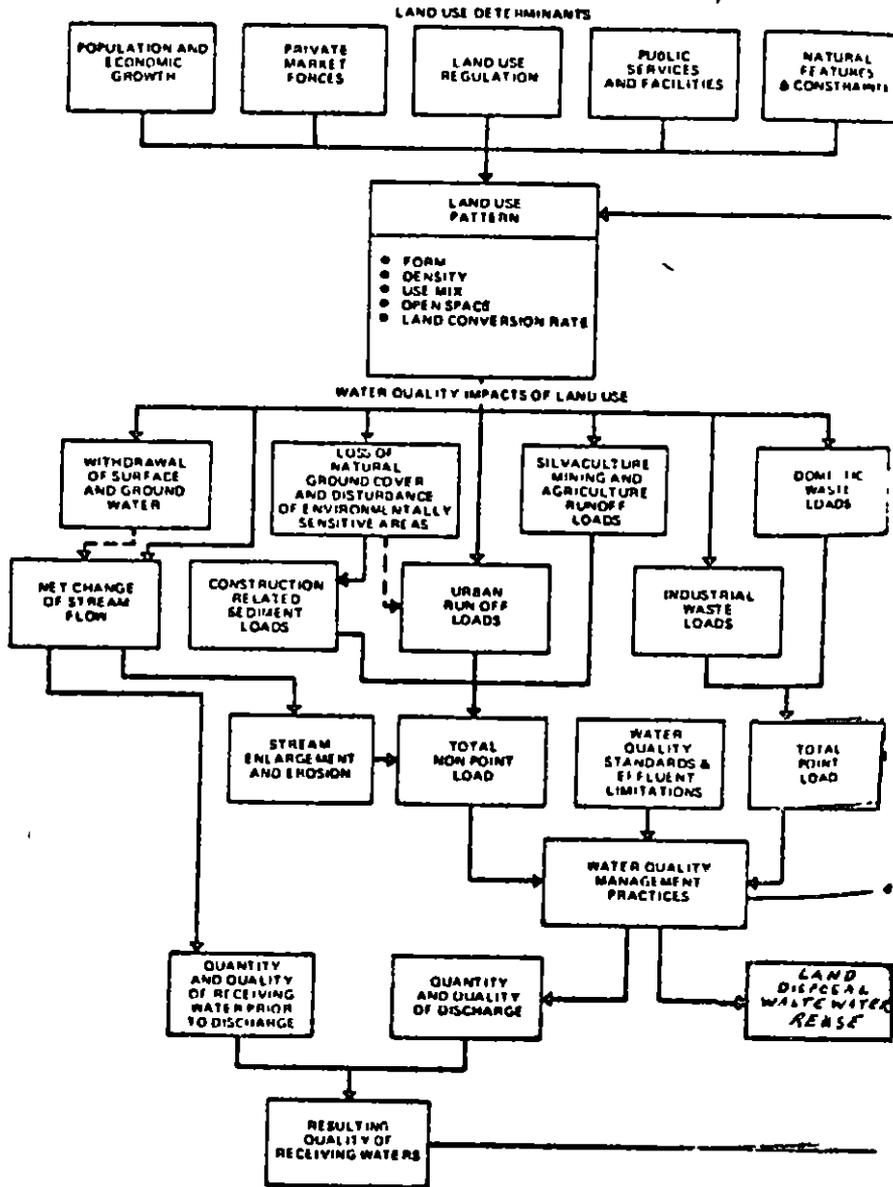Schematic Diagram of the Land Use/Water Quality
Relationship

TABLE 1

EROSION RATES REPORTED FOR VARIOUS SEDIMENT SOURCES

Sediment Source	Erosion Rate ton/sq mi /year	Geographic Location	Comment
Natural	15-20	Potomac River Basin	Native Cover
	32-192		Native Cover
	200	Pennsylvania and Virginia	Natural Drainage Basin
	320	Mississippi River Basin	Throughout Geologic History
	13-83	Northern Mississippi	Forested Watershed
	25-100	Northwest New Jersey	Forest and Under Developed Land
	115		Soils Eroding at the Rate They Form
Agricultural	12,800	Missouri Valley	Loess Region
	13,900	Northern Mississippi	Cultivated Land
	1,030	Northern Mississippi	Pasture Land
	10,000-70,000		Continuous Row Crop Without Conserva tion Practices
	200-500	Eastern U S Piedmont	Farmland
	320-3,840		Established as Tolerable Erosion
Urban	50 50,000	Kensington, Maryland	Undergoing Extensive Construction
	1,000-100,000		Small Urban Con- struction Area
	1,000	Washington, D C. Area	750 Square Mile Area Average
	500	Philadelphia Area	
	146	Washington, D C. Area	As Urbanization
	280	Watersheds	Increases
	690		
	2,300		
Highway Construction	36,000	Fairfax Co., VA	Construction on 179 Acres
	50,000-150,000	Georgia	Cut Slopes

-14-

Table 2: REPRESENTATIVE RATES OF EROSION FROM VARIOUS LAND USES

	Metric Tons/ sq km/year	Tons/ sq mi/year	Relative to Forest = 1
Forest	8.5	24	1
Grassland	85	240	10
Abandoned Surface Mines	850	2,400	100
Cropland	1,700	4,800	200
Harvested Forest	4,250	12,000	500
Active Surface Mines	17,000	48,000	2,000
Construction	17,000	48,000	2,000

RELATIVE EROSION FROM VARIOUS LAND USES· NATIONWIDE

Commercial Forests	1
Abandoned Surface Mines	< 1
Active Surface Mines	2
Construction	6
Harvested Forests	11
Grassland	11
Cropland	168

283

Figure 3

Relationship of Drainage Area Sediment Yield
and Construction Activity Suburban Maryland
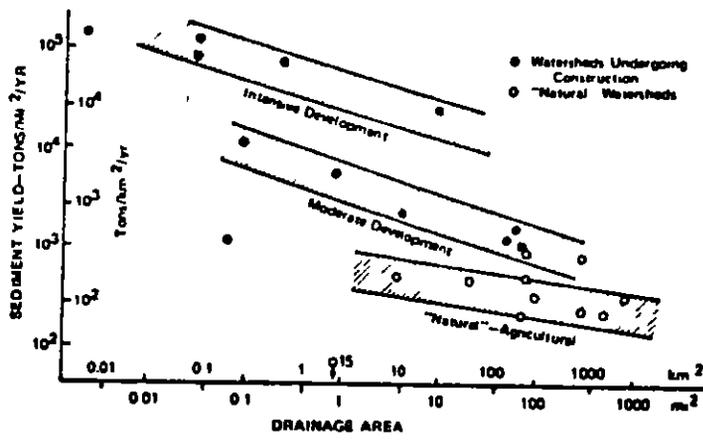
Table 3

Annual Non-Point Pollutional Impacts by Land Use

LAND USE	QUALITY PARAMETERS						
	IMPERVIOUSNESS (DEGREE)	BOD LBS/ ACRE/ YEAR	N LBS/ ACRE/ YEAR	P LBS/ ACRE/ YEAR	PO₄ LBS/ ACRE/ YEAR	EROSION	TEMPERATURE CHANGE
NATURAL FORESTS (& HA LANDS)	LOW	SMALL	89	009	3	LOW	///////
AGRICULTURE (FARMS)	LOW		24 / 24	97 / 3 HR		HIGH POTENTIAL	SMALL
FEEDLOTS	HIGH	VARYING WITH ANIMAL TYPE DENSITY & MANAGEMENT PRACTICES				HIGH POTENTIAL	SMALL
SINGLE FAMILY RESIDENTIAL	LOW MEDIUM	59	6	2	0	///////	VARIES WITH DEGREE OF COVER REMOVED AND SURFACES HEATED (5° to 18°)
MULTI FAMILY RESIDENTIAL	MEDIUM	14	25	67	21	///////	
COMMERCIAL	HIGH	43	24	13	39	///////	
INDUSTRIAL	VERY HIGH	234	33	50	17	///////	
RESOURCE EXTRACTION	VARIES WITH METHODOLOGY AND MANAGEMENT PRACTICES						
RECREATION	VARIES WITH INTENSITY OF USE–EXTREMELY SENSITIVE TO OVERUSE						
URBAN & ROAD CONSTRUCTION						30,000– 150,000 TONS/ACRE	

TABLE 4

SUMMARY OF REPORTED NUTRITIONAL LOADINGS

Source	Nitrogen Pounds/Acre/Year	Phosphorous Pounds/Acre/Year
Farmland runoff	--	0.35 (Total-P)
Good management	1.0 (NO_3-N)	0.10 (PO_4-P)
Poor management	5.3 (NO_3-N)	0.25 (PO_4-P)
4 lb/A/yr applied	0.7-3.0(Total-N)	0.06-0.2 (Total-P)
Irrigation return flow	2.45-24.0(Total-N)	0.95-3.88(Total-P)
Urban runoff	8.2 (Total-N)	0.87 (Total-P)
	2.95-15.97(organic-N)	3.32-20.20 (PO_4-P)
Rainfall at 30"/yr	4.8-32 (NO_3-N)	0.18-0.54 (PO_4-P)
	0.14-9.5 (inorganic-N)	--
	10 (N)	—
Forest runoff	1.30-2.96 (Total-N)	0.32-0.77 (Total-P)
	0.5 (Total-N)	0.03-0.06 (Total-P)
leaf litter	6.5×10^{-7} (NO_3-N)	—
Domestic waste	lb/cap/yr 6.9-10.7 (Total-N)	lb/cap/yr 1.3-3.8 (Total-P)
Septic tanks	8 (NO_3-N, ground water seepage)	
Waterfowl	lb/duck/yr 1.2 (inorganic-N)	lb/duck/yr 0.3 (Total-P)

TABLE 5

AGRICULTURAL POLLUTIONAL LOADS

	TOTAL N (Lbs/Acre/Year)	TOTAL P (Lbs/Acre/Year)
Surface	2.45 - 28 3	0.68 - 3.99
Subsurface	38 - 166	2.5 - 8.9

Source: Sylvester, Robert O., <u>Algae and Metropolitan Wastes, Transactions of the 1960 Seminar</u>, U S Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1961. (Bartsch, Alfred F., Ed.) (3)

Witzel, Stanley A., <u>Nitrogen Cycle in Surface and Subsurface Waters</u>, Water Resources Center, The University of Wisconsin, December 1968. (23)

TABLE 6

SUMMARY OF REPORTED BOD LOADS

Source	Load	
Urban runoff, 34" rainfall/yr	30.5 lb/Acre/year	
Rural cultivated land runoff	0 5-23 mg/l	
Silo drainage	4400 mg/l	
Stock floor washings	2000 mg/l	
Rainfall	9-16 mg/l COD	
Domestic waste	73 lb/cap/year	
Industrial waste	lb/unit produced	mg/l
Explosives	320/100,000 lb TNT	1070
Synthetic fibers	77/1000 lb product	713
Paper and pulp	53/ton product	266
Poultry	26.1/1000 chickens	476
Sugar beet	13/ton produce	580
Meat packing	12/1000 lb live wt	1384
Tanning	4.55/100 lb hides	806
Brewery	2.6/barrel	964
Textile	2.45/100 lb each process	440
Milk	1.16/1000 lb intake	857
Cannery	0.365/case	1188

TABLE 7: TYPICAL COMPOSITION OF DOMESTIC-SEWAGE
(All values in mg/liter)

Constituent	Strong	Medium	Weak
Solids, total	1000	500	200
Volatile	700	350	120
Fixed	300	150	80
Suspended, total	500	300	100
Volatile	400	250	70
Fixed	100	50	30
Dissolved, total	500	200	100
Volatile	300	100	50
Fixed	200	100.	50
BOD (5-day, 20 degrees C)	300	200	100
Oxygen consumed	150	75	30
Dissolved oxygen	0	0	0
Nitrogen, total	66	50	25
Organic	35	20	10
Free ammonia	50	30	15
Nitrites (NO_2)	0.10	0.05	0
Nitrates (NO_3)	0.40	0.20	0.10
Chlorides	175	100	15
Alkalinity	200	100	50
Fats	40	20	0

TABLE 8

SUMMARY OF BACTERIAL LOADS

Source	Coliform/100 ml	Coliform/cap-day
Raw sewage	1,000,000	3.7×10^9
Treated sewage		
Primary treatment	500,000	1.8×10^9
Activated sludge	60,000	2.3×10^8
Biological plus		
chlorination	15,000	5.7×10^7
Urban runoff 34" rainfall/yr	1,275,000	5.5×10^{10}/A-day
Irrigation returns	--	insignificant

VI. Existing Surface Water Quality and Quantity

A. Water Quantity

1. Sources of information --- U.S. Geological Survey, Oklahoma Water Resources Board.

2. Example data for Mountain Fork River near Eagletown, Oklahoma. See Table 9 and Figure 4. (·2)

   10% of time flow $\geq$ 3,500 cfs
   50% of time flow $\geq$ 350 cfs
   90% of time flow $\geq$ 10 cfs

B. Water Quality

1. Sources of information --- STORET (EPA), OWRB, USGS.

2. See Table 10 for data on Rock River near Oregon, Illinois. (Some reported parameters eliminated)

3. To interpret the water quality data, need to compare to standards. The following rating system was used in one study:

   (a) number zero was given as score when the quality parameters met applicable standards.

   (b) when standards not met, negative values assigned.

4. Table 11 used as a basis for the negative values. The rational for Table 11 is as follows.

   (a) Not meeting a bacteriological quality standard was three times as important as not meeting a physical quality standard, and not meeting a chemical quality was twice as important; therefore, the negative numerical assignments for the bacteriological classification were three times greater than those for the physical classification, and the chemical classification assignments were two times greater.

TABLE 9
SURFACE WATER RECORDS REGION V AND VI
STREAM GAGING STATIONS

3390   MOUNTAIN FORK RIVER NEAR EAGLETOWN, OKLAHOMA.

Drainage area - 787 sq mi
Average discharge - 39 years, 915,800 acre-feet per year
Extremes - Maximum discharge, 101,000 cfs, May 20, 1960   Minimum, no flow at times

Monthly and Yearly Discharge, in Acre-Feet

Water Year	Oct	Nov	Dec.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	The Year
1951	17,220	9,610	5,260	36,050	235,500	78,600	67,900	42,890	131,400	151,400	5,930	10,460	792,200
1952	21,850	128,700	94,120	102,700	71,340	122,200	435,600	47,960	6,850	808	137	1 0	1,032,000
1953	0	69,420	79,300	83,460	99,250	209,000	319,500	256,300	4 600	151,000	8 310	1 090	1,291,000
1954	101	1,070	20,900	149,000	97,350	19,100	72,800	146,600	4,650	313	1 6	6,980	515,900
1955	171,600	27,720	57,510	61,690	117,000	153,000	103,400	66,830	11,920	5,170	5,690	16,590	804,100
1956	28,560	2,370	5,210	17,070	212,300	50,760	29,490	68,000	3,240	540	192	257	418,700
1957	4 8	16,150	43,880	124,000	114,700	177,100	487,700	302,400	138,500	5,350	2,660	34,520	1,447,000
1958	10,440	117,200	58,060	97,800	33,710	217,900	152,300	223,800	55,320	14,150	14,350	16,100	1,005,000
1959	21,650	157,100	26,860	31,150	64,150	131,400	80,490	42,700	17,610	54,410	9,910	10,220	647,700
1960	87,530	29,620	210,900	146,800	93,320	83,960	42,210	311,600	42,670	93,000	38,040	5,050	1,185,000
1961	5,970	11,050	240,500	63,140	94,930	164,600	91,490	161,900	17,810	54,420	24,290	16,960	979,100
1962	27,170	133,200	152,400	172,500	103,000	106,400	106,200	25,110	14,390	1,370	2,940	11,360	656,000
1963	111,600	43,530	30,060	40,780	10,640	135,900	56,870	25,540	2,240	4,190	2,750	1,1 0	465,300
1964	22	0	921	976	19,660	157,100	177,000	29,430	2,840	127	32,210	49,630	470,700
1965	20,400	76,390	38,010	77,320	208,300	77,860	48,240	165,500	110,700	8,980	841	24,510	857,100
1966	12,140	6,300	12,560	32,410	157,200	32,190	120,400	130,300	2,570	456	36,630	8,960	552,100
1967	1,050	1,090	6,920	11,270	13,110	58,540	157,200	194,500	78,460	48,060	1,640	14,410	586,200

Compiled from U. S Geological Survey Surface Water Records

Location —Lot 34°07 30   Long 94°37 15   on down
stream side of pier of bridge on U S Highway
70 2 miles west of Eagletown and at mile 8 9
Drainage area —787 sq mi
Average discharge —37 years (water years 1925
1930 65) 1 291 cfs (934 600 acre ft per year)
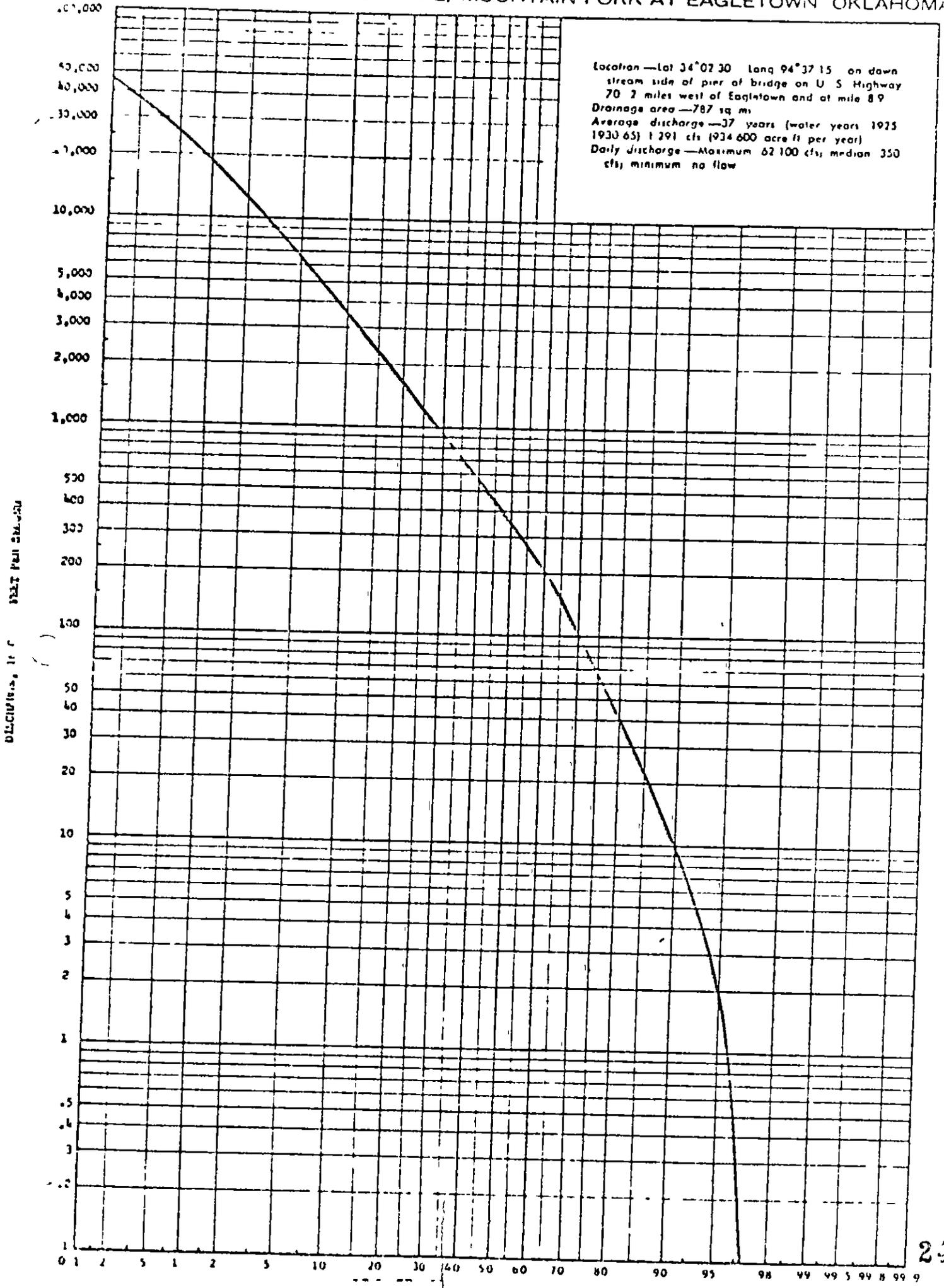Daily discharge —Maximum 62 100 cfs; median 350
cfs; minimum no flow

213

TABLE 10

STORET IDENTIFICATION NO.   47096

STREAM.   Rock River

STATION LOCATION   Route 64 Town Bridge near Oregon, Illinois

MAP NO..   47096 on Figure 2 4.3.1.4-2

PARAMETER	Units	No. of Samples	Begin Date	End Date	Mean	Max	Min	STANDARD
Physical								
Turbidity	JTU	71	62/06/04	72/05/22	65	230	0	
Tot. Diss. Solids	mg/l	61	62/06/04	72/06/27	347	(570)	*	500
Temperature	°F	72	62/06/04	72/06/27	56	82	32	90
Susp. Solids	mg/l	-						
Chemical								
pH	SU	69	62/06/04	72/06/27	*	*	*	6.5-9.0
Hardness	mg/l	33	62/06/04	71/12/01	289	376	144	
Diss Oxygen	mg/l	67	62/06/04	72/06/27	*	*	(0)	5.0
BOD_5	mg/l	26	62/06/04	67/07/06	6	10	2	30
Hydrocarbons	mg/l	-						
Ammonia	mg/l	43	62/06/04	72/06/27	1.1	(18)	0.0	1.5
NO_2 & NO_3	mg/l	47	62/06/04	72/06/27	2.4	(70)	0.0	10
Phosphates	mg/l	33	64/05/21	71/12/01	(11)	(35)	0.0	0.15
Bacteriological:								
Fecal Coliform	MPN/100ml	14	62/06/04	72/06/27	226	(1900)	0	400

*Erroneous STORET data.

TABLE 11

NUMERICAL ASSIGNMENTS FOR
STREAM QUALITY RATING SYSTEM

No. of Samples	Value	Numerical Assignments for Parameter Classifications		
		Physical	Chemical	Bacteriological
Less than 10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Mean	-3	-6	-9
10 or more	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Mean	-6	-12	-18

(b) When the mean value of a parameter does not meet the applicable standard, it is three times as important as the maximum or minimum value not meeting the standard; therefore, the negative numerical assignments for the mean values were three times greater than those for the maximum or minimum values.

(c) Stations from which ten or more samples have been analyzed are twice as important as those stations from which fewer than ten samples have been analyzed, therefore, the negative numerical assignments for stations with ten or more samples were twice as great as the comparable assignments for stations with less than ten samples.

5. Following the determination of a numerical score for each station based on a composite summation of negative numerical assignments applied when standards were not met, each station was assigned a rating on the following basis·

   N = no quality data available

   A = meets all existing standards; good water quality; score = 0

   B = meets most of existing standards, moderately good water quality; score = -1 to -10

   C = does not meet few existing standards; fair water quality; score = -11 to -30

   D = does not meet several existing standards; poor water quality, score = -31 and greater

6. Application of the stream water quality rating system to the data in Table 10 is as follows:

$$TDS = -2$$

$$DO = -4$$

$$Ammonia = -4$$

$$NO_2 \text{ and } NO_3 = -4$$

$$PO_4 = -4 \text{ and } -16$$

$$Fecal = \underline{-6}$$

$$Total = -36 \quad \text{(D category)}$$

Table 12 represents a summary of the application of this system to several Illinois streams.

VII. Unique Pollution Problems (Step 3)

    A. Purpose

        1. The primary objective is to note any unique pollution problems which have occurred in the surface watercourses of the area.

        2. For example, fish kills, algae growth or thermal discharges causing stratified flow.

    B. Sources of Information

        1. Oklahoma Water Resources Board

        2. State Health Department

        3. Newspapers

        4. Conservation groups

VIII. Groundwater Quantity and Quality (Step 4)

    A. Purpose

        1. Describe the groundwater flow and quality in the area, noting particularly the depth to the groundwater table and the direction of flow.

TABLE 12

ILLINOIS STREAM QUALITY RATING

Stream	Map No.	No. of Reported Parameters			Values		Score	Rating
		1-4	5-8	9-13	<10	≥10		
Apple River	48482			X	X		-16	C
Plum R.	48480			X	X		-20	C
Vermilion R.	48037			X		X	-40	D
Rock River	47094			X		X	-30	C
Rock River	47096			X		X	-36	D
Rock River	47097			X	X		-13	C
Rock River	48001			X	X		-4	B
Rock River	4435	X			X		0	A
Rock River	48180			X		X	-20	C
Rock River	48039			X		X	-64	D
Rock River	48181			X		X	-20	C
Rock River	47095			X		X	-32	D
Rock River	47090			X		X	-32	D
Rock River	47091			X		X	-30	C
Rock River	47092			X		X	-44	D
Elkhorn River	48514			X	X		-11	C
Kankakee River	46094			X		X	-54	D
Kankakee River	48562			X	X		-4	B
Kankakee River	48094			X		X	-62	D
Kankakee River	48089			X		X	-70	D
Kankakee River	48424			X	X		0	A
Kankakee River	46093			X		X	-24	C
Iroquois River	46095			X		X	-36	D
Iroquois River	48426			X	X		0	A
Iroquois River	48425			X	X		-12	C
Mazon River	48393		X		X		-10	B
Mazon River	48394		X		X		-35	D
Illinois River	5685	X			X		0	A
Illinois River	5435	X			X		0	A
Illinois River	48365			X	X		-29	C
Illinois River	48367			X	X		-25	C
Illinois River	160067			X		X	-42	D
Illinois River	5599			X		X	-30	C

2. Also identify major users of groundwater in the area.

3. Note any historical trends in groundwater depletion.

B. Sources of Information

    1. Oklahoma Water Resources Board

    2. U.S. Geological Survey

    3. Oklahoma Geological Survey

    4. State Health Department

IX. Summarize Meteorological Information (Step 5)

A. Assemble Monthly Records of Precipitation, Evaporation, Temperature.

B. National Oceanographic and Atmospheric Administration, Environmental Data Service, Asheville, N.C.

X. Water Quality Standards (Step 6)

A. PL 92-500 Federal Water Pollution Control Act Amendments of 1972 (13)

    1. Some basic goals and policies:

        (a) The discharge of pollutants into navigable water be eliminated by 1985.

        (b) Wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and out of the water be acheived by July 1, 1983.

        (c) The discharge of toxic pollutants in toxic amounts be eliminated. (prohibited)

B. Strategies for Point Source Control

    1. NPDES permit system

2. Every point source subject to an effluent standard and a water quality standard. Most stringent one is used.

3. Effluent standards

   (a) by 1977

   POTW —— secondary treatment

   others —— BPT

   (b) by 1983

   POTW —— BPWTT

   others —— BAT

   (c) new sources —— NSPS

   (d) within 3 yrs. —— pretreatment

C. Definition of Terms (14)

   1. The best practicable technology and best available technology, which industries are required to use by 1977 and 1983 respect-ively, take into account such factors as age of equipment, facilities involved, process employed and process changes, en-gineering aspects of control techniques, and environmental impact apart from water quality, including energy requirements.

   2. In assessing best practicable technology for a particular category of industry, a balance is struck between total cost and effluent reduction benefits.

   3. Best available technology is the highest degree of technology proved to be designable for plant-scale operation so that costs for this treatment may be much higher than for treatment by best practicable technology.

   4. Best available demonstrated technology, which will be the basis for establishing effluent limits for new industries, is described

as those plant processes and control technologies that have demonstrated at a pilot plant level that technologically and economically they justify making investments in new production facilities.

5. Secondary treatment is a method of purifying waste water using biological processes. Up to 90 percent of the organic matter in sewage is removed by making use of the bacteria in it. The principal methods are by filter, in which the waste passes through a thick bed of stones, and by the activated sludge process wherein organic matter, pumped into an aeration tank, is broken down by the addition of air and bacteria-laden sludge. The solids are removed to a sedimentation tank and the effluent is chlorinated.

D. Pretreatment Standards

1. Federal Register, Vol 38, No. 215, Thursday, Nov. 8, 1973, pp. 30982-30984. (15)

2. Deals basically with industrial plant waste clean-up prior to discharge into POTW.

3. Examples of focus

   (a) pH

   (b) toxic metals

   (c) flow variations

E. Secondary Treatment Standards

1. Federal Register, Vol. 38, No. 159, Friday, August 17, 1973, pp 22298-22299. (16)

2. Describes treatment efficiency level and effluent quality from POTW.

244

3. Focus on:

   (a) BOD

   (b) suspended solids

   (c) coliforms

F. Water Quality Standards

   1. Oklahoma will be used as an example. "Oklahoma's Water Quality Standards - 1973", Pub 52, OWRB, Sept., 1973. (17)

   2. Antidegradation Statement

      It is recognized that certain of the waters under consideration possess an existing quality, which is better than the minimum standards established. The quality of those waters will be maintained, unless and until it has been affirmatively demonstrated to the State through public hearings that other uses or different standards are justifiable as a result of necessary economic or social development. This will require that any industrial, public, or private project or development which would constitute a new source of pollution or an increased source of pollution to high quality waters will be required, as part of the initial project design, to provide the highest and the best degree of waste treatment.

   3. Benefical use designations

      The designated present and potential beneficial uses of the waters of the State are A, C_1, D, F_1, F_2, G_1, G_2, and I, and the general water quality standards apply unless otherwise noted in Appendix A. Published data for some

-34-

streams are limited. However, appropriate beneficial uses
to be protected are specified even though low flow condi-
tions may for the most part prevent such uses as primary
body contact recreation. Beneficial uses of Oklahoma sur-
face waters designated herein specify quality objectives
of lakes and streams. The designation does not limit bene-
ficial use nor prohibit beneficial uses other than those
listed nor does it indicate by the order listed any pre-
ference of uses. It is recognized that beneficial uses
may be protected where corresponding activities are other-
wise prohibited by law or by private ownership. This
would include primary body contact in some public water
supplies as well as recreational use of some privately
owned waters. All reservoirs are protected for primary
and secondary body contact recreation.

CODE	BENEFICIAL USE
A	Public and private water supplies
B	Emergency public and private water supplies
C_1	Fish and wildlife propagation
C_2	Fish and wildlife propagation to the extent allowed by specifically stated water quality parameters
D	Agriculture (includes livestock watering and irrigation)
E	Hydroelectric power
F_1	Industrial and municipal cooling water
F_2	Receiving, transporting and/or assimilation of adequately treated waste
G_1	Recreation, primary body contact (includes recreational uses where the

human body may come in direct contact with the water to

point of complete body submergence)

G₂ Recreation, secondary body contact (includes recreational uses, such as fishing, wading, boating, where ingestion of water is not probable)

H   Navigation

I   Aesthetics

J   Small-mouth bass fishery excluding lake waters

K   Trout fishery (put-and-take)

CODE   LIMITATION

(a) All streams and reservoirs designated (a) are protected by prohibition of any future discharge of pollutants.

(b) All streams designated (b) are return flow streams for which special water quality standards have been established.

(c) Streams or stream systems in which advanced waste treatment of all waste discharges is required are designated (c).

4. General Standards

The instream numerical criteria limits shall be maintained at all times with the exception of when the flow is equal to or less than the seven-day, two-year low flow value or times when the flow rate is not significant or discernable by the naked eye. The numerical criteria limits apply at all times to lakes and reservoirs unless otherwise exempted.

Minerals:

For chlorides, sulfates and total dissolved solids the arithmetic mean of the concentrations of the samples taken for a year at any point shall not exceed one standard deviation

greater than the arithmetic mean of the historical data generated at that point. Not more than one in twenty samples randomly collected shall exceed two standard deviations greater than the arithmetic mean of the historical data generated at that point   Mineralization from other parameters such as calcium, boron, magnesium and sodium from other than natural sources shall be maintained so as to not restrict the beneficial uses. For those stations for which historical data exists, mineral limits have been established and are listed in Appendix B. The values are in milligrams per liter (mg/l). The stations are organized in accordance to basin number with each station's number corresponding to those on Map 2. Mineral standards will be established for other stations as data becomes available. The term "yearly mean standard" listed on the table is defined as that value which the yearly arithmetic mean shall not exceed. The term "sample standard" is used on the table and is defined as that value which not more than one in twenty samples shall exceed. Mineral limits for intermediate locations between listed sample points shall be determined by allowing reasonable gradients between the numerical limits listed for those stations.

Bacteria:

In areas designated as G_1 (recreation, primary body contact) or A (public and private water supply), bacteria of the fecal coliform group shall not exceed a monthly geometric

-37-

mean of 200/100 ml, as determined by multiple-tube fermenta-

tion or membrane filter procedures and based on a minimum

of not less than five samples for any 30-day period, nor

shall more than ten percent (10%) of the total samples

during any 30-day period exceed 400/100 ml.

In areas designated G_2 (secondary body contact) bacteria

of the fecal coliform group shall not exceed a monthly

geometric mean of 1000/100 ml, as determined by multiple-

tube fermentation or membrane filter procedures, nor

shall more than ten percent (10%) of the total samples

during any 30-day period exceed 2000/100 ml.

Oil and Grease:

Essentially free of floating or emulsified oil and grease.

Solids:

Free of floating debris, bottom deposits, scum, foam and

other materials of a persistent nature from other than

natural sources.

Turbidity:

Turbidity of other than natural origin shall be restricted

to the following in-stream numerical values:

Warm Water Streams	50 Jackson Units
Warm Water Lakes	25 Jackson Units
Cold Water Streams (those designated as small-mouth bass fisheries or trout fisheries	10 Jackson Units

In waters where the natural occurring backgrounds exceeds

these values, turbidity from other than natural sources

shall be restricted to maintain the naturally occurring

background.

Color

Color producing substances of a persistent nature from
other than natural sources shall be limited to concentra-
tions which will not be detrimental to beneficial uses

Temperature·

During any month of the year, heat shall not be added to
any stream in excess of the amount that will raise the
temperature of the water more than $5^{o}F$. In lakes, the
temperature of the epilimnion shall not be raised more than
$3^{o}F$ above that which existed before the addition of heat
of artificial origin. The normal daily and seasonal tem-
perature variations that were present before the addition
of heat due to other than natural causes shall be main-
tained. The maximum temperature due to man-made causes
shall not exceed $68^{o}F$ in trout streams, $84^{o}F$ in small-
mouth bass streams, or $90^{o}F$ in all other streams and
lakes except for the following:

> Arkansas River from Kaw Reservoir Dam to the headwaters
> of Keystone Reservoir 94OF.
> Arkansas River from Keystone Reservoir Dam to Coody
> Creek near Muskogee, Oklahoma 93OF.
> Salt Fork Arkansas River 93OF.
> Red River excluding Lake Texoma $93^{o}F$.
> North Fork Red River 91OF.

No artificial heat shall be added such that the receiving
water temperature exceeds the maximums specified above.
Privately owned lakes and reservoirs used in the process of
cooling water for industrial purposes are exempt from these
restrictions provided the water released from any such lake

-39-

2 4

or reservoir shall be subject to the temperature require-
ments   Maximum temperature determination shall be made
by averaging representative temperature measurements of
the cross sectional area of streams and rivers.

Taste and Odor Producing Substances

Taste and odor producing substances from other than natur-
al origin shall be limited to concentrations that will not
interfere with the production of potable water by modern
treatment methods or impart off-color or unpalatable flavor
to flesh of fish, or result in offensive odors in the vi-
cinity of the water, or otherwise interfere with beneficial
uses.

Dissolved Oxygen

The dissolved oxygen concentration shall not be less than
5 mg/l for all warm waters, and 6 mg/l for those waters
designated as small-mouth bass or trout fisheries. Under
extreme conditions, the diurnal variations may cause the
dissolved oxygen concentration to be as much as 1 mg/l
below the above values for short periods (not to exceed 8
hours) during any 24-hour period provided that the water
quality is favorable in all other respects.

Nutrients

The total phosphorous concentration and Nitrogen/Phosphorous
ratio shall be limited to prevent eutrophication problems.
If sufficient nutrient date become available specific numeri-
cal limits will be included in the water quality standards
revision scheduled for October 18, 1975.

Toxic substances shall not be present in such quantities
as to cause the waters to be toxic to human, animal, plant
or aquatic life, nor detrimental to any beneficial use
including continued ingestion by livestock or continued
use for irrigation. For aquatic life, using bioassay
techniques, the toxic limit shall not exceed one-tenth of
the 96-hour median tolerance limit for the most sensitive
species common to the stream. In the absence of informa-
tion on the most sensitive species the concentration shall
not exceed one-tenth of the 96-hour median tolerance
limit to Pimephales promelas (Fathead Minnow) and/or Lepomis
macrochirus (Bluegill).

Toxic substances shall not be present in quantities which
allow long term toxic effects in the food chain or accumu-
lation of toxic substances in fish or wildlife.

The following materials may have synergistic effects:
ammonia, cadmium, hexavalent chromium, trivalent chromium,
copper, cyanide, lead, mercury, nickel, selenium, silver,
and zinc These substances shall not be present in suffi-
cient concentration to allow the cumulative relationship
value to exceed the numerical value of one.

The cumulative relationship value (CRV) is defined as.

$$CRV = \frac{C_a}{L_a} + \frac{C_b}{L_b} + \ldots + \frac{C_n}{L_n}$$

where: C_a, C_b, ...C_n are the measured concentrations in the
streams and L_a, L_b, ...L_n are respective maximum permissable
concentrations if each constituent were present alone.

-41-

Species Diversity Index·

A diversity value $(\overline{d})$ for benthic (bottom dwelling) macro-
invertebrate organisms shall be maintained at a minimum
of three (3) unless natural conditions or phenomena cause
the value to be less.

Enumeration and classification techniques of sampled ben-
thic organisms shall be utilized to acquire information
which will be subjected to mathematical interpretation
from which is derived an index of species diversity $(\overline{d})$.
Biological information incorporated into the diversity
index includes: number of species samples (s), total
number of individuals (n), and number of individuals per
species (n_1); with diversity specifically expressed
mathematically as:

$$\overline{d} = -\sum_{1}^{s} (n_1/n) \log_2 (n_1/n)$$

This expression is dimensionless and includes numbers of
individuals representing each species. The species di-
versity index shall not be determined on a count of less
than 100 individuals per sample.

pH:

The pH shall be between 6.5 and 8.5. pH values below 6.5
and above 8.5 must not be due to waste discharge.

Other Substances:

The control of other substances not heretofore mentioned
will be guided by the U.S. Public Health Service Drinking

-42-

Water Standards of 1962, or latest revision thereof, and accumulated scientific data on limits above which injury to use occurs. Pollutional substances will be maintained below maximum permissible concentrations for public water supplies, recreation requirements, agricultural needs and other beneficial uses.

5. Special Standards

Return Flow Streams.

(a) Dissolved Oxygen: The dissolved oxygen content of a return flow stream shall not be less than 2 mg/l. The dissolved oxygen concentration just above the point where the flow of the stream combines with the flow of a stream of higher designated use shall not be less than 3 mg/l.

(b) Species Diversity Index: The species diversity index shall not apply to return flow streams.

Mixing Zones and Zones of Passage

(a) Mixing Zones: Except as indicated below, mixing zones shall be no larger than one-fourth (1/4) the cross sectional area of the stream or not more than one-fourth (1/4) the volume of flow, whichever is most restrictive. The remaining portion of the stream's cross section or flow shall constitute a zone of passage for free swimming and drifting organisms. Where more than one effluent enters a stream and the mixing zones would overlap, the combined mixing shall not exceed the one-fourth (1/4) value described above. The mixing zone shall begin at the point of discharge and extend downstream to the point of complete mixing.

Special mixing zones shall be designated where return

flows exceed one-fourth (1/4) of the combined stream and

return flows.

Mixing zones in lakes shall be designated on a case by

case basis.

    (b) Exceptions to beneficials uses Mixing zones may be as-

signed all of the beneficial uses for which the natural

waters of that stream would be satisfactory with the ex-

ception of the following

        (1) Public and private water supply, A

        (2) Emergency public and private water supply, B

        (3) Fish and wildlife propagation, C_1

        (4) Recreation (primary and secondary body contact), G_1, G_2

    (c) Dissolved Oxygen· The dissolved oxygen shall not be less

than 2 mg/1 within the mixing zone.

  6. Example of water quality standards in Oklahoma. See Figure 5

and Table 13 and 14.

G. Nationwide Comparison (' &)

  1. Effluent-limited segments vs. water-quality limited segments.

  2. 1973 inventory of river segments in the states: 3,100 polluted

segments

      Effluent-limited = 1,515

      W.Q. - limited = <u>1,588</u>

               3,103

  3. W.Q. limited means that the effluent standards are not stringent

enough, thus more stringent controls required on point sources.
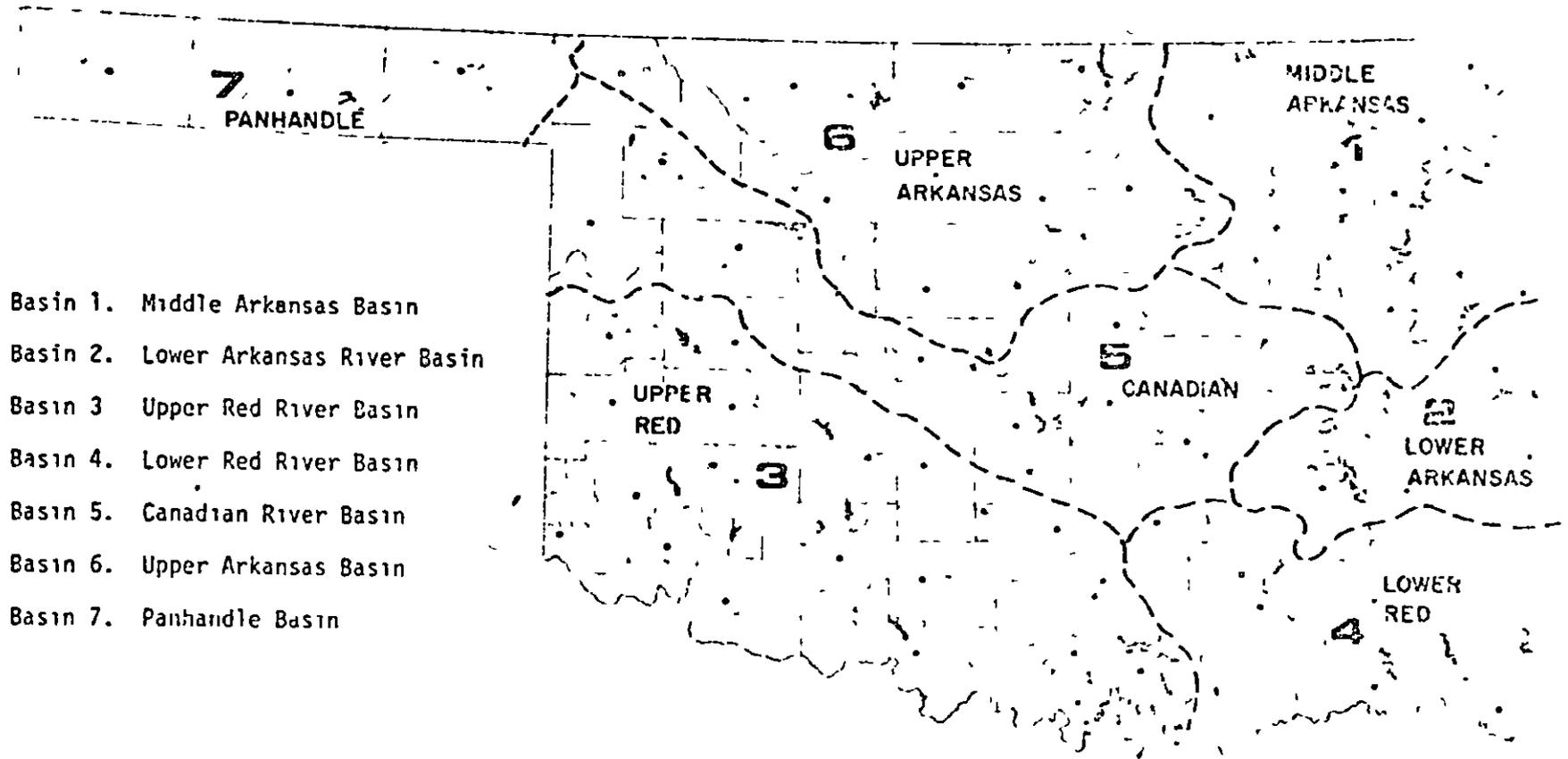
Basin 1. Middle Arkansas Basin

Basin 2. Lower Arkansas River Basin

Basin 3 Upper Red River Basin

Basin 4. Lower Red River Basin

Basin 5. Canadian River Basin

Basin 6. Upper Arkansas Basin

Basin 7. Panhandle Basin

Water Quality Management
Planning Basins

Figure 5

Basin #5

TABLE 13

Stream

N. Persimmon Creek

S Persimmon Creek

Indian Creek

Wolf Creek below Ft Supply Dam

Wolf Creek above Ft Supply Dam including Ft. Supply Reservoir

Sixteen Mile Creek

Buzzard Creek

L Wolf Creek

Twenty-Five Mile Creek

Willow Creek

Rock Creek

Otter Creek

Clear Creek

Little River

Salt Creek

Lake Thunderbird and Watershed

Unnamed tributary (return flow, City of Konowa) including Lake Konowa

Sandy Creek

Spring Creek

Pond Creek

Buckhead Creek

-97-

Beneficial Uses	Other Limitations
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
C_2 D F_1 F_2 G_2 I	b
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
A C_1 D F_1 F_2 G_1 G_2 I	
C_2 D F_1 F_2 G_2 I	b
A C_1 D G_1 G_2 I	a
C_2 D F_1 F_2 G_2 I	b
C_2 D F_1 F_2 G_2 I	b
A C_1 D F_1 F_2 G_1 G_2 I	
C_2 D F_1 F_2 G_2 I	b
C_2 D F_1 I G_2 I	b

Sample Point Name	Map Number	Latitude and Longitude	Chloride Sample Standard	Chloride Yearly Mean Standard	Sulfate Sample Standard	Sulfate Yearly Mean Standard	Total Dissolved Solids Sample Standard	Total Dissolved Solids Yearly Mean Standard
West Salt Creek near Chickasha, Oklahoma	3283	35 09 00.0 097 57 00 0	243	168	701	506	1764	1324
West Bitter Creek near Tabler, Oklahoma	3283.1	35 03 00 0 097 51 00 0	32	23	370	257	834	630
Spring Creek near Blanchard, Oklahoma	3284	35 06 50 0 097 44 30 0	19 3	14 6	29	23	468	356
Spring Creek Tributary near Middleberg, Oklahoma	3283.2	35 05 00 0 097 50 00 0	17 5	12 8	18.3	14 4	391	322
Foss Reservoir near Foss, Oklahoma	3243	35 32 18 0 099 10 40 0	52	48	1177	1112	1935	1849

BASIN 4

Sample Point Name	Map Number	Latitude and Longitude	Chloride Sample Standard	Chloride Yearly Mean Standard	Sulfate Sample Standard	Sulfate Yearly Mean Standard	Total Dissolved Solids Sample Standard	Total Dissolved Solids Yearly Mean Standard
Kiamichi River near Big Cedar, Oklahoma	3357	34 38 18 0 094 36 45 0	4.6	3 4	6.5	4 9	33	28

BASIN 5

Sample Point Name	Map Number	Latitude and Longitude	Chloride Sample Standard	Chloride Yearly Mean Standard	Sulfate Sample Standard	Sulfate Yearly Mean Standard	Total Dissolved Solids Sample Standard	Total Dissolved Solids Yearly Mean Standard
Canadian River near Bridgeport, Oklahoma	2285	35 34 00 0 098 22 45 0	351	232	490	389	1497	1162
Canadian River near Noble, Oklahoma	2291	35 04 55 0 097 27 52 0	291	206	391	287	1227	906
Lake Thunderbird near Norman, Oklahoma	2299	35 13 15 0 097 13 05 0	31	29	18.6	14 9	285	263
Little River near Sasakwa, Oklahoma	2310	34 59 02 0 096 33 01 0	1382	990	60	45	2802	2046
Canton Lake near Canton, Oklahoma	2385	36 05 03 0 098 36 05 0	346	298	233	225	4051	2603

4. All segments presumably should meet the w.q standards by 1977, however, estimate is that only 1,190 segments can do this; and, total of only 2,306 by 1983.

H. Federal Discharges (.'7)

1. The Federal Water Pollution Control Act requires all U S. Government agencies to comply with Federal, State, interstate and local water pollution control laws and regulations, just as any non-governmental source of pollution must. As part of that compliance, Federal installations dicharging pollutants into water bodies are covered by the NPDES permit system Permits for discharges from Federal installations are issued only by EPA, however. Thus, even if a U.S. military base, power plant, hospital, munitions plant, etc is located in a State that has an EPA-approved permit program, EPA, not the State, is the permit authority for that Federal installation

2. The law empowers the President to exempt any Federal effluent source from compliance if it's "in the paramount interest" of the Nation to do so. (However, no exemption may be granted from the new source performance standards and effluent standards for toxic pollutants that EPA will issue in 1974, nor from compliance with pretreatment requirements for wastes going directly into a publicly-owned treatment plant.)

3. The President may not grant an exemption because of the lack of funds to bring a Federal facility into compliance unless he has specifically asked Congress for the funds, and Congress has failed to appropriate the money.

4. The law also requires the President to report annually to Congress all exemptions granted, with the reason for each exemption.

XI. Waste Load Allocation Study (Step 7)

    A. Purposes

        1. Summarize the waste load allocation study for the area. (26)

        2. Identify the known point sources of pollution, noting particularly any unique discharges or constituents.

            (a) State Health Department

            (b) Oklahoma Water Resources Board

            (c) Department of Pollution Control

        3. Also identify the quantity and types of water uses in the area

            (a) hydraulic balance --- important in water-deficient areas

            (b) quality requirements per industrial use, see Table 15. (21)

            (c) SHD, OWRB, DPC

    B. Most States Are Developing or Have Recently Completed These Studies

XII. Mesoscale Impact Calculation (Step 8)

    A. Purpose --- to examine impact of alternatives in terms of their relative contribution to a stream's waste load.

    B. Assessment of Impact --- View in terms of percentage increase in pollutant loads.

XIII. Construction Phase Impacts (Step 9)

    A. Primary Focus on Sediments.

    B. Summary of Sediment Prediction Methods in Table 16. (22)

-49-

2 3

TABLE 15

Summary of Specific Quality Characteristics of Surface Waters That Have Been Used as Sources for Industrial Water Supplies

(Unless otherwise indicated units are mg/l and values are maximums. No one water will have all the maximum values shown.)

Characteristic	Boiler makeup water — Industrial 0 to 1 500 psig	Utility 700 to 5 000 psig	Cooling water — Fresh — Once through	Fresh — Makeup recycle	Brackish¹ — Once through	Brackish¹ — makeup recycle	Process water — Textile Indus ry SIC-22	Lumber indu-try SIC-24	Pulp and paper industry SIC-26	Chemical industry SIC-28	Petroleum Industry SIC-29	Prim metals Industry SIC-33	Food and kindred products, SIC-20	Leather Industry, SIC-31
Silica (SiO₂)	150	150	50	150	25	25	-----	-----	50	-----	50	-----	For the above 2 categories the quality of raw surface supply should be that prescribed by the NTA Sub committee on Water Quality Requirements for Public Water Supplies	
Aluminum (Al)	3	3	3	3	-----	-----	-----	-----	-----	-----	-----	-----		
Iron (Fe)	80	80	14	80	1 0	1 0	-----	-----	-----	-----	-----	-----		
Manganese (Mn)	10	10	2 5	10	0 02	0 02	0 3	-----	2 6	5	15	-----		
Copper (Cu)	-----	-----	-----	-----	-----	-----	1 0	-----	-----	2	-----	-----		
Calcium (Ca)	-----	-----	500	500	1,200	1,200	0 5	-----	-----	-----	-----	-----		
Magnesium (Mg)	-----	-----	-----	-----	-----	-----	-----	-----	-----	200	220	-----		
Sodium and potassium (Na K)	-----	-----	-----	-----	-----	-----	-----	-----	-----	100	85	-----		
Ammonia (NH₃)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	230	-----		
Bicarbonate (HCO₃)	600	600	600	600	180	180	-----	-----	-----	-----	-----	-----		
Sulfate (SO₄)	1,400	1 400	680	680	2,700	2,700	-----	-----	-----	600	480	-----		
Chloride (Cl)	19,000	19 000	600	500	22 000	22,000	-----	-----	-----	850	570	-----		
Fluoride (F)	-----	-----	-----	-----	-----	-----	-----	-----	200 *	500	1 600	500		
Nitrate (NO₃)	-----	-----	30	30	-----	-----	-----	-----	-----	-----	1 2		
Phosphate (PO₄)	-----	50	4	4	5	5	-----	-----	-----	-----	8		
Dissolved solids	35 000	35 000	1 000	1 000	35 000	35 000	-----	-----	-----	-----	-----	-----		
Suspended solids	15 000	15 000	5 000	15 000	250	250	150	-----	1,080	2 500	3 500	1 500		
Hardness (CaCO₃)	5 000	5 000	850	850	7 000	7 000	1,000	(³)	-----	10 000	5 000	3 000		
Alkalinity (CaCO₃)	500	500	500	500	150	150	120	-----	475	1 000	900	1,000		
Acidity (CaCO₃)	1 000	1,000	0	200	0	0	-----	-----	-----	500	-----	200		
pH units	-----	-----	5 0-8 9	3 5-9 1	5 0-8 4	5 0-8 4	6 0-8 0	5-9	4 6-9 4	5 5-9 0	6 0-9 0	3-9		
Color units	1,200	1 200	-----	1,200	-----	-----	-----	-----	-----	-----	25	75		
Organics							-----	-----	360	500				
Methylene blue active substances	2⁴	10	1 3	1 3	-----	1 3	-----	-----	-----	-----	-----	-----		
Carbon tetrachloride extract	100	100	(⁵)	100	(⁵)	100	-----	-----	-----	-----	-----	-----		
Chemical oxygen demand (O₂)	100	500	-----	100	-----	200	-----	-----	-----	-----	-----	30		
Hydrogen sulfide (H₂S)	-----	-----	-----	-----	4	4	-----	-----	-----	-----	-----	-----		
Temperature, F	120	120	100	120	100	120	-----	-----	95 *	-----	-----	100		

¹ Water containing in excess of 1 000 mg/l dissolved solids
² May be 1 000 for mechanical pulping operations
³ No large particles ≥3 mm diameter
⁴ 1 mg/l for pressures up to 700 psig
⁵ No floating oil

* Applies to bleached chemical pulp and paper only

NOTE — Application of the above values should be based on Part 23 ASTM book of standards 1) or APHA Standard methods for the examination of water and waste water (J)

TABLE 16

SUMMARY OF SEDIMENT PREDICTION METHODS

Prediction Method	Process		
	Erosion	Transport	Deposition
1. Empirical			
Ellison[21]	X	-	-
Musgrave[67]	X	-	-
Universal Soil Loss Equation[118]	X	-	-
Einstein Bedload Function[41]	-	X	-
Colby Modified Einstein[41]	-	X	-
Toffaleti Total Load Method[41]	-	X	X
Lacey's Silt Theory[37]	-	X	X
Pemberton Modified Einstein[77]	-	X	-
Reservoir Surveys:	-	-	X
ARS			
SCS			
Corps of Engineers			
Bureau of Reclamation			
U.S. Geological Survey			
2. Statistical			
Flaxman[34]	-	-	X
Sediment Rating-Flow Duration:	-	-	X
U.S. Geological Survey			
Bureau of Reclamation			
Corps of Engineers			
Woolhiser's Deterministic Watershed Model[119]	X	X	X
3. Simulation			
ARS Upland Erosion Model[38]	X	-	-
ARS USDAHL-73 Watershed Model[50]	X	X	X
ARS "ACTMO" Chemical Transport Model[74]	-	X	-
Negev's Watershed Model[71]	X	X	X
Stanford IV Model[13]	X	X	X
Hydrocomp Simulation[12]	X	X	X
Huff Hydrologic Transport Model[51]	-	X	-
Royal Institute (Sweden) Hydrologic Model[5]	X	X	X
Snyder's Parametric Hydrologic Model[86]	-	X	X

-51-

XIV. Microscale Impact Calculation (Step 10)

   A. Conservative Pollutants --- use mass balance calculations.

   B. Non-Conservative Pollutants --- see dissolved oxygen sag curve

       materials.

   C. Temperature --- see temperature prediction materials.

 XV. Pollution Control Measures (Step 10)

   A. Purpose is to Minimize Impact

   B. Many Reference Materials are Available. $(23)(24)(25)$

XVI. Discuss Operational Impacts (Step 11)

   A. See Bacterial Die-Away Precition Materials.

   B. Example of Chemical Changes in Aqueous Systems (26)

       1. Cr in Water

           trivalent Cr (III)   cation $Cr(OH)^{+2}$

           hexavalent Cr (VI)   anion $Cr\ O_4^{-2}$

       2. Cr (III) is more chemically reactive than Cr (VI)

       3. Source in streams is nuclear power plants --- release Cr (VI)

       4. Fate in stream depends on oxidation state

           Cr(III) is sorbed and settles

           Cr(VI) stays in solution

       5. Oxidation state in stream can change:

           (a) Cr (VI) can be chemically reduced to Cr (III) under anaero-

                bic conditions.

           (b) Cr (VI) stays as Cr (VI) under aerobic conditions

(c) Cr (III) can be oxidized to Cr (VI) under aerobic conditions.

(d) Cr (VI) which is sorbed is later released as Cr (III)

(e) Cr (III) stays as Cr (III) under anaerobic conditions

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Assessment of the Impact of Organic
Discharges on the Dissolved Oxygen
Resources of a Receiving Stream

by

L.W. Canter*

One of the most common problems of stream pollution is that
resulting from oxygen deficiency caused by organic waste discharges.
Dissolved oxygen in a stream is deficient when the actual concentra-
tion is less than the saturation concentration. Nemerow and Velz have
recently published excellent books which describe the myriad considera-
tions involved in stream pollution analysis (1,2). This discussion
represents only a cursory presentation of dissolved oxygen relationships
in streams.

I. Dissolved Oxygen

   A. Dissolved oxygen is one of the primary chemical parameters used
      to describe water quality. Dissolved oxygen is basic to the
      maintenance and promotion of aquatic flora and fauna.

   B. Water quality standards have been established for dissolved
      oxygen, some examples from Oklahoma standards are (3):

      1. General standards

*Director, School of Civil Engineering and Environmental Science,
University of Oklahoma, Norman, Oklahoma.

a. The instream numerical criteria limits shall be maintained at all times with the exception of when the flow is equal to or less than the seven-day, two-year low flow value or times when the flow rate is not significant or discernible by the naked eye The numerical criteria limits apply at all times to lakes and reservoirs unless otherwise exempted

b. Dissolved Oxygen. The dissolved oxygen concentration shall not be less than 5 mg/l for all warm waters, and 6 mg/l for those waters designated as small-mouth bass or trout fisheries. Under extreme conditions, the diurnal variations may cause the dissolved oxygen concentration to be as much as 1 mg/l below the above values for short periods (not to exceed 8 hours) during any 24-hour period provided that the water quality is favorable in all other respects.

c. Special Standards - Return low streams

Dissolved Oxygen: The dissolved oxygen content of a return flow stream shall not be less that 2 mg/l The dissolved oxygen concentration just above the point where the flow of the stream combines with the flow of a stream of higher designated use shall not be less than 3 mg/l.

3. Special Standards - Mixing Zones and Zones of Passage

a. Mixing Zones Except as indicated below, mixing

zones shall be no larger than one-fourth (¼) the cross sectional area of the stream or no more than one-fourth (¼) the volume of flow, whichever is most restrictive The remaining portion of the stream's cross section or flow shall constitute a zone of passage for free swimming and drifting organisms Where more than one effluent enters a stream and the mixing zones would overlap, the combined mixing zones shall not exceed the one-fourth (¼) value described above The mixing zone shall begin at the point of discharge and extend downstream to the point of complete mixing.

Special mixing zones shall be designated where return flows exceed one-fourth (¼) of the combined stream and return flows.

Mixing zones in lakes shall be designated on a case by case basis

b. Dissolved Oxygen   The dissolved oxygen shall not be less than 2 mg/l within the mixing zone

C. Saturation Dissolved Oxygen

   1. If water is saturated with dissolved oxygen, it means that the water contains 100% of the dissolved oxygen it could contain under specified conditions of temperature, pressure and salt content.

2,

2. Influence of temperature on the saturation concentration of dissolved oxygen

Saturation D.O.

Temperature
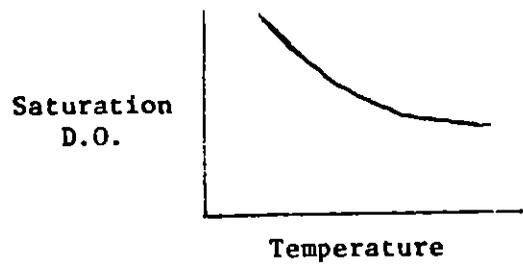
3. Influence of pressure on the saturation concentration of oxygen

Saturation D.O.

Pressure
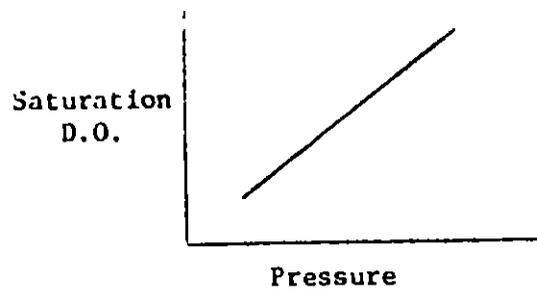
4. Influence of salt content on the saturation concentration of oxygen, mainly on conern in sea water.

Saturation D.O.
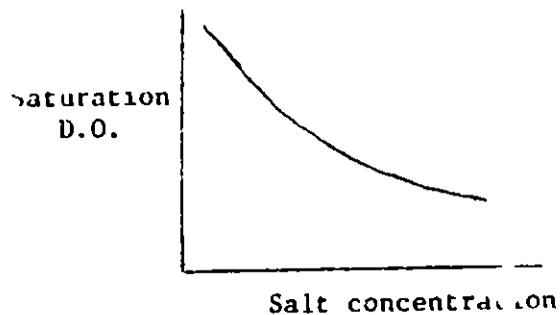
Salt concentration

5. he actual concentration of dissolved oxygen in polluted water is generally less than the saturation concentration

$$\text{Deficit} = D = \text{saturation concentration} - \text{actual concentration}$$

(Cs)

-4-

Example   Temperature of $25^{\circ}C$, normal atmospheric pressu

and non-sea water, if the measured D.O. is 2 0

mg/l, what is th. deficit?

Cs = 8 18 mg/l

D = 8 18 - 2.0 = 6 18 mg/l

II. Oxygen Relationships in Streams

A. Basic Forces

1. There is a demand for oxygen exerted by bacterial decomp -

sition of organics, shown in simplified equation which

follows

$$\text{Organics} + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O$$
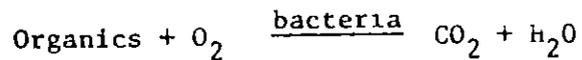
2. There is a supply of oxygen from natural reaeration.

3. Other forces are oxygen demand from bottom deposits and

oxygen supply from photosynthesis.

4. The basic forces of organic oxygen demand and natural re-

tion yield what is called an oxygen sag curve

Time or distance
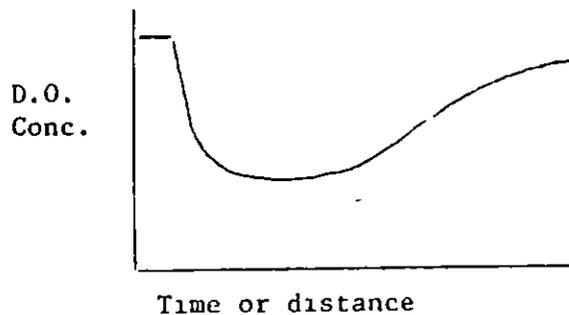
B Streeter-Phelps Equation

1 Originally developed in 1 25

2. Assumptions for oxygen sag curve

a. BOD decrease dye only by bacterial oxidation

b. No benthal O_2 demand

c. No photosynthetic effec

d. Reoxygenation by reaeration

3. Basic differential equation

$$\frac{dD}{dt} = \text{oxygen demand} - \text{oxygen supply}$$

$$= K_1 L - K_2 D$$

where

K_1 = rate of oxygen use by bacteria

L = biochemical oxygen demand

K_2 = rate of reaeration

4. Solution of the basic differential equation yields the following:

$$D = \frac{K_1 La}{K_2 - K_1} \left(10^{-K_1 t} - 10^{-K_2 t} \right) + Da\, 10^{-K_2 t}$$

D = D.O. deficit at time t

= sat. conc - actual conc

K_1 = coef. of deoxygenation

k_2 = coef. of reaeration

La = initial BOD (ultimate) (in stream)

Da = initial deficit (in stream)

5. K_1 = coef. of deoxygenation

determined in BOD test at $20°C$

$$k_{1(T)} = K_{1(20)} (1.047)^{T-20}$$

T = temp. $(°C)$

6   $K_2 = \phi$(surface exposure, depth, turbulence, velocity)

   - Tables or Calculations -

   $$K_{2(T)} = K_{2(20)} \ (1\ 016)^{T-20}$$

7. $La_{(T)} = la_{(20)} \ (0\ 02T + 0.6)$

8   Influence of temperature on the oxygen sag curve (see Fig ╷

9   Critical Conditions

   Location and value of low point on curve.

   Distance
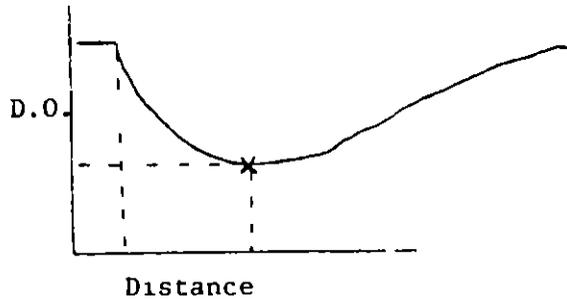
a   Critical time

   $$t_c = \frac{1}{K_2-K_1} \ \log_{10}\left(\frac{K_1La-K_2Da+K_1Da}{K_1La} \ \frac{K_2}{K_1}\right)$$

b.   Critical deficit

   $$Dc = \frac{K_1}{K_2} \ La \ 10^{-K_1tc}$$

10.   Maximum Permissable BOD Load

   Rearrange Streeter-Phelps as follows

   $$\log La = \log Dc + \left[1 + \frac{K_1}{K_2-K_1} \left(1 - \frac{Da}{Dc}\right)^{0\ 418}\right] \log$$

      La = ultimate BOD   mg/l)

      Dc = allowable defi .t = saturation

         DO conc - req ired DO conc in standard

      Da = initial deficit

FIGURE I (26)

RELATION BETWEEN TEMPERATURE AND OXYGEN PROFILE
(After La Berge)

Miles from Outlet Discharging Organic Waste
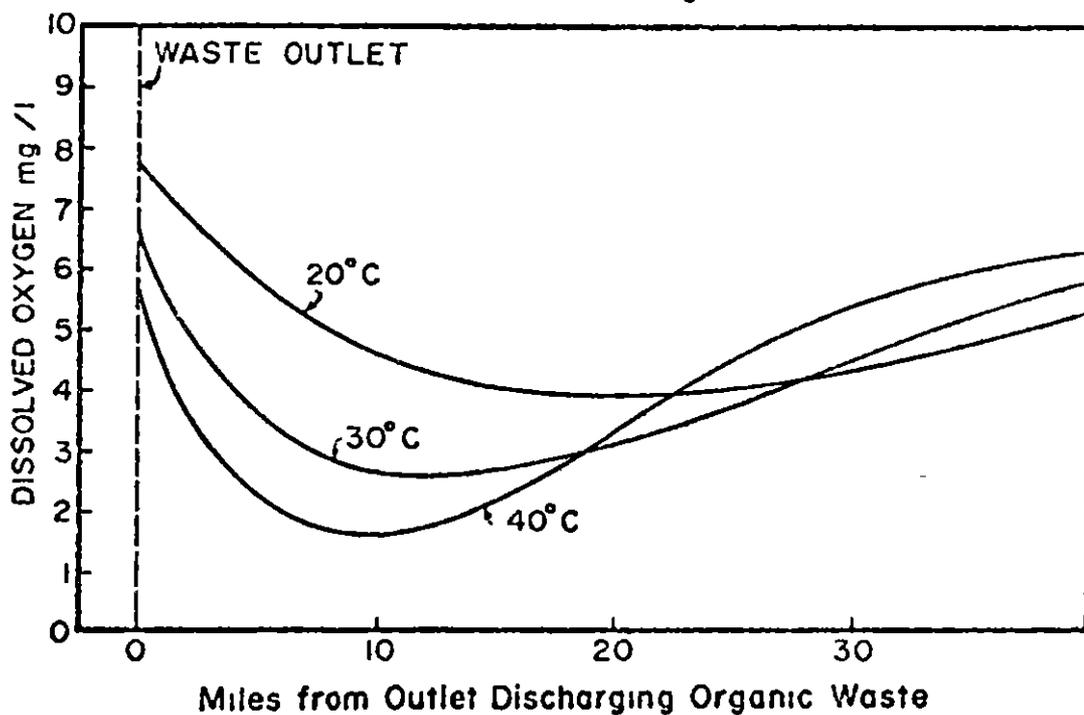
K_1 = BOD reaction rate

K_2 = reaeration rate

C. Thomas modification of Streeter-Phelps equation

1. It is known that stream deoxygenation (Kd) values differ from K_1.

2. Deoxygenation is stream by oxidation.

$$\frac{dD}{dt} = K_D L_t$$

  D = oxygen deficit

  Kd = coef of deoxygenation, not equal to K_1 in BOD bottles in lab, includes only deoxygenation by oxidation in stream

  Lt = oxidizable organic matter remaining at any time t
$$= La \; 10^{-K_1 t}$$

  La = initial oxidizable organic matter at t=o (in stream)

  K_1 = rate of oxidation from laboratory

  t = time

3. Combining above the rate of deoxygenation may be expressed as follows:

$$\frac{dD}{dt} = K_D L_a \; 10^{-K_1 t}$$

This equation expresses the rate of deoxygenation in terms of the coefficient of deoxygenation (K_D) and the laboratory rate of oxidation (K_1).

4. The practical considerations to be answered not is whether the rate of oxidation determined in the laboratory (K_1) is identical to the rate of organic (BOD) removal determined in the actual receiving water

-9-

2G9

K_r = rate of BOD removal in the stream itself

$$K_r = K_3 + K_1$$

If the answer is negative then the above equation should be expressed as:

$$\frac{dD}{dt} = K_D \, La \, 10^{-K_r t}$$

5. Environmental factors that affect the rate of oxidation

Condition	Probable Relationship between K_r and K_1
a) Turbulence	$K_r > K_1$ (BOD removal in stream > BOD removal in bottle)
b) Biological Growth on Stream bed	$K_r > K_1$
c) Immediate O_2 demand	$K_r > K_1$
d) Nutrient deficiency in stream	$K_r < K_1$
e) Toxic conditions	$K_r < K_1$

6. Environmental factors affecting the rate of organic material removal in the receiving stream but not necessarily the rate of oxidation

Condition	Probable Relationship between K_r and K_1
Sedimentation and Flocculation taking away	$K_r > K_1$
Scour adding	$K_r < K_1$
Volatilization taking away	$K_r > K_1$

7. Overall relationship between K_r, K_d and K_l

    a. If the reactions in the stream were identical to the reactions in the laboratory then

$$K_l = K_r = K_D$$

    b. If BOD removal in the stream was by oxidation only but the rate was increased by turbulence or slime growths on the stream bottom then it may be assumed that

$$K_r \searrow K_l \quad \text{but } K_D = K_r$$

    c. If BOD removal in the stream was accomplished by a combination of oxidation and sedimentation, scour, volatilization then it may be assumed that

$$K_r \searrow K_l \quad \text{but } K_D = K_l$$

8. Thomas equ integrates to

$$D = \frac{K_D La}{K_2 - K_r} \left[10^{-K_r t} - 10^{-K_2 t} \right] + Da 10^{-K_2 t}$$

9. Determine K_r

$$K_r = \frac{1}{t} \log \frac{L_A}{L_B}$$

    K_r is rate of BOD removal, not necessarily just oxidation.

    t = time of flow between stations A and B
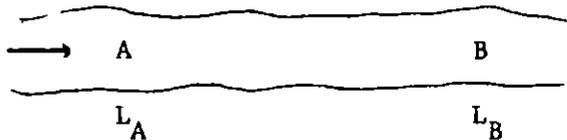
    L_A = BOD loading at sta. A (lb/day)

    L_B = "   "   "   "   B (")

-11-
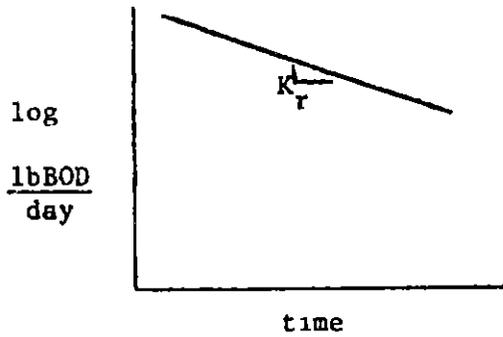
10. K_2

    a. determine by equation

    b. use O'Connor equ.

11. K_D

    a. difficult to determine

    b. may get help from above considerations

    c. may have to assume a K_D value and confirm by survey.
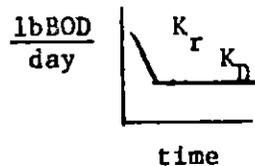
12. Critical deficit

$$\frac{dD}{dt} = K_D L \quad - K_2 D$$

$$\frac{dD}{dt} = 0$$

$$D = \frac{K_D}{K_2} L = \frac{K_D}{K_2} La \ 10^{-K_r t_c}$$

13. Critical time

$$t_c = \frac{1}{K_2 - K_r} \ \log \left[\frac{K_2}{K_r} \left(1 - \frac{Da(K_2 - K_r)}{K_D La} \right) \right]$$

D. Churchill-Buckingham equation

    1. By using multiple linear correlation on TVA streams, Churchill and Buckingham found good correlation between

BOD

DO

temp.

stream flow

2. He found for TVA streams that D.O. sag is function of only

   three variables.

   a. BOD

   b. temp.

   c. stream flow

3. Used least-squares method of analysis.

4. Advantages

   a. fewer samples needed

   b. do not need K_2, K_r, etc.

5. Disadvantages

   a. applicability to other streams?

   b. omits many factors

6. Equation

   $Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3$

   Y = D.O. drop (mg/l)

   $a = 4.136$

   $b_1 = -0.122$

   X_1 = BOD at sag (mg/l)

   $b_2 = -0.532$

   X_2 = temp at sag ($^\circ$C)

   $b_3 = 0.709$ X_3 = flow at sag (1000 cfs)

E. Photosynthesis

$$D = \frac{K_D}{K_2 - K_r} \left[La - \frac{B}{K_r} \right] \left[10^{-K_r t} - 10^{-K_2 t} \right]$$

$$+ \frac{K_D}{K_2} \left[\frac{B}{K_r} \right] \left[1 - 10^{-K_2 t} \right] + Da \, 10^{-K_2 t}$$

7. Equation including photosynthesis and bottom deposits.

$$D = \frac{K_D}{K_2 - K_r} \left[La - \frac{B}{K_r} \right] \left[10^{-K_r t} - 10^{-K_2 t} \right]$$

$$+ \frac{K_D}{K_2} \left[\frac{B}{K_r} - \frac{P}{K_D} \right] \left[1 - 10^{-K_2 t} \right] + Da \, 10^{-K_2 t}$$

1. Concept

    a. day

$$CO_2 + H_2O + algae + nutrients \xrightarrow{\hspace{1cm}}$$

          new algae + O_2 - heat
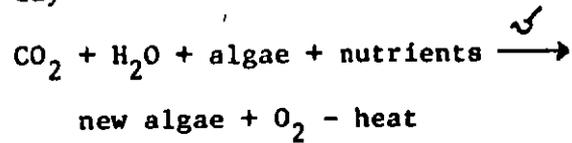
          during day algae is source of O_2

    b. night

$$algae + O_2 \longrightarrow CO_2 + H_2O$$
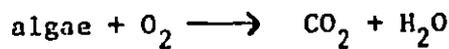
          during night using O_2

2. S-P, Thomas, C-B omit photosynthesis as an O_2 source. Some suggest to include a term for this.

3. O'Connor, etc. have advocated term added

4. Equation

$$\frac{dD}{dt} = K_D L - K_2 D - P$$

    P - net O_2 production by photosynthesis (mg/l/day)

F. Bottom deposits

1. Bottom deposits can exert a demand on the oxygen resources of a stream.

2. This is like adding an additional BOD load.

3. Concept

$$\frac{dL}{dt} = -K_r L + B$$

    B = addition of BOD load to the overlying water from the bottom. (mg/l/day)

4. Sort of like scour, except this occurs all the time

5. This was modification added by Camp.

6. Equation including bottom deposits

PREDICTION OF BACTERIAL
SELF-PURFICATION IN
STREAMS

by
L.W. Canter*

In order to assess the potential environmental impact of a proposed

action, it may be necessary to predict bacterial self-purification in

streams. This discussion is oriented to the principles of bacterial self-

purification in streams as well as the mathematical techniques available

for describing these phenomena.

I. Introduction

    A. Bacterial Self-Purification

        1. Definition --- the decrease of bacteria of all types, and

            especially those of fecal origin, as a function of flow dis-

            tance or flow time in a river.

        2. Bacteria may starve to death, be devoured by predators, or

            be otherwise inactivated.

    B. Classic Work --- early work by Streeter and his co-workers in

        Cincinnati on the Ohio River. (1920's)

    C. Pathogenic Microorganisms

---

*Director, School of Civil Engineering and Environmental Science, Univer-
sity of Oklahoma, Norman, Oklahoma.

Selected References on Impact of Organics

1. Nemeron, Nelson L., <u>Scientific Stream Pollution Analysis</u>, McGraw-Hill Book Company, New York, 1974, 358 pages.

2. Velz, Clarence J., <u>Applied Stream Sanitation</u>, Wiley-Interscience, John Wiley and Sons, Inc., New York, 1970, 619 pages.

3. "Oklahoma's Water Quality Standards-1973" Publication No. 52, Oklahoma Water Resources Board, Oklahoma City, Oklahoma, 1973, pp. 3-9.

Table 1: Expected Seasonal Pattern of Monthly Average Coliform Contribution Based on an Annual Average of 200 Billion per Capita per Day

Month	Monthly Average (Percentage of Annual Average)	Monthly Average Coliform Contribution per Capita per Day ($\times 10^9$)
January	45	90
February	46	92
March	53	106
April	65	130
May	92	184
June	135	270
July	172	344
August	182	364
September	165	330
October	110	220
November	80	160
December	55	110
Annual average	100	200

1. Special public health concern with the disposal and ultimate fate of microbial wastes contained in municipal sewage, especially those of intestinal origin that cause waterborne diseases. These are principally pathogenic bacteria and viruses, and the cysts and ova of parasitic worms.

2. Examples of pathogenic bacteria and their associated diseases.

    (a) Salmonella typhi --- typhoid fever

    (b) Shigella and Salmonella organisms --- dysentery and diarrhea, respectively

    (c) Vibrio comma --- cholera

    (d) Mycobacterium tuberculosis --- tuberculosis

3. Example of amoebas --- Entamoeba histolytica is known to have caused epidemics of amoebic dysentery.

4. Viruses have been known to cause infectious hepatitis.

D. Indicator Organisms and Enumeration

1. Coliforms (non-pathogenic bacteria) and fecal coliforms are used as indicator organisms.

2. Values reported as "most probable number" (MPN).

E. Per Capita Contribution and Seasonal Variation

1. Coliform generation rate
   200×10^9/capita/day

2. Typical seasonal variations are shown in Table 1. Whether these variations are traceable to actual multiplication of intestinal bacteria within the sewers or to a greater per capita discharge of these organisms in the summer months cannot be stated.

F. General Principles of Self-Purification

Table 2: Killing Times for the First 90% (T_{90})
of Enteric Bacteria in River Water

Organism	Medium	Temp., °C	T_{90}, hours
			60
E. coli	Ohio River	Summer	47
		Winter	51
	Missouri River	Winter	115
	Tennessee River	Summer	53
	Sacramento River	Summer	32
	Cumberland River	Summer	10
	Glatt River	Summer/winter	2.1[a]
S. typhi	Thames River	0	172
		5	108
		10	77

[a] Small shallow streams.

1. Some general conclusions of Streeter's work are as follows:

    (a) The maximum density of coliforms occurs at some distance downstream of a source of pollution

    (b) based upon the maximum numbers of organisms, the percentage of surviving cells downstream follows a curve with a slightly decreasing slope when a log linear plot is applied

    (c) the variance of single observations rapidly increases with a diminishing of the absolute numbers of organisms

2. Representative killing times for the first 90% of enteric bacteria in river water are shown in Table 2.

3. Killing rates of bacteria in natural streams depend largely on the hydraulic and biological characteristics of the stream. In shallow rivers, where a large ratio of wetted surface to water flow exists, and a considerable amount of fixed biomass is normally present, rate constants for the initial part of the death rate curves (e.g., until T_{90}) of coliforms might be found which are 20 or more times higher than reported from the Ohio River (see examples in Table 2).

4. Increasing temperature enhances bacterial disappearance considerably.

5. The influence of the organic pollution load on the persistence of coliforms or other fecal bacteria in a river is controversial. The multiplication of pathogenic organisms in natural waters is certainly negligible (sediments very rich in fecal matter may be an exception) Dissolved organic pollutants

-4-
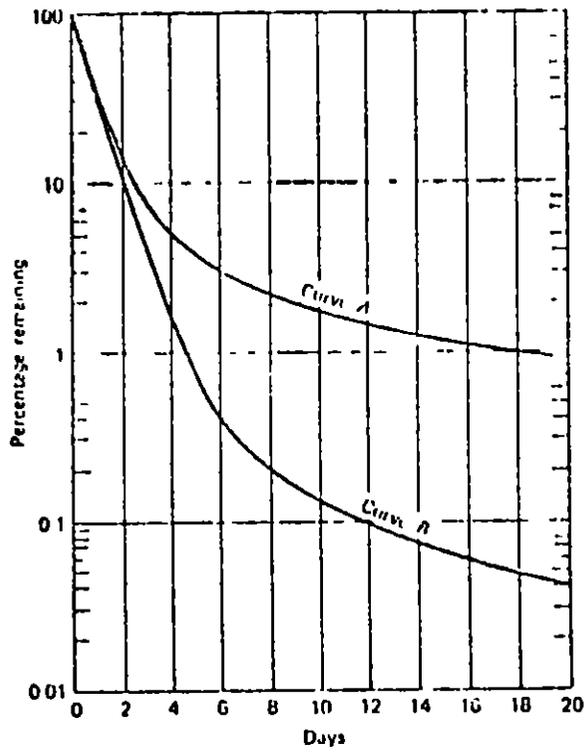
Figure 19 Death rate curves of *E. coli* in the Ohio River Curve *A* cool-weather conditions, curve *B* warm-weather conditions
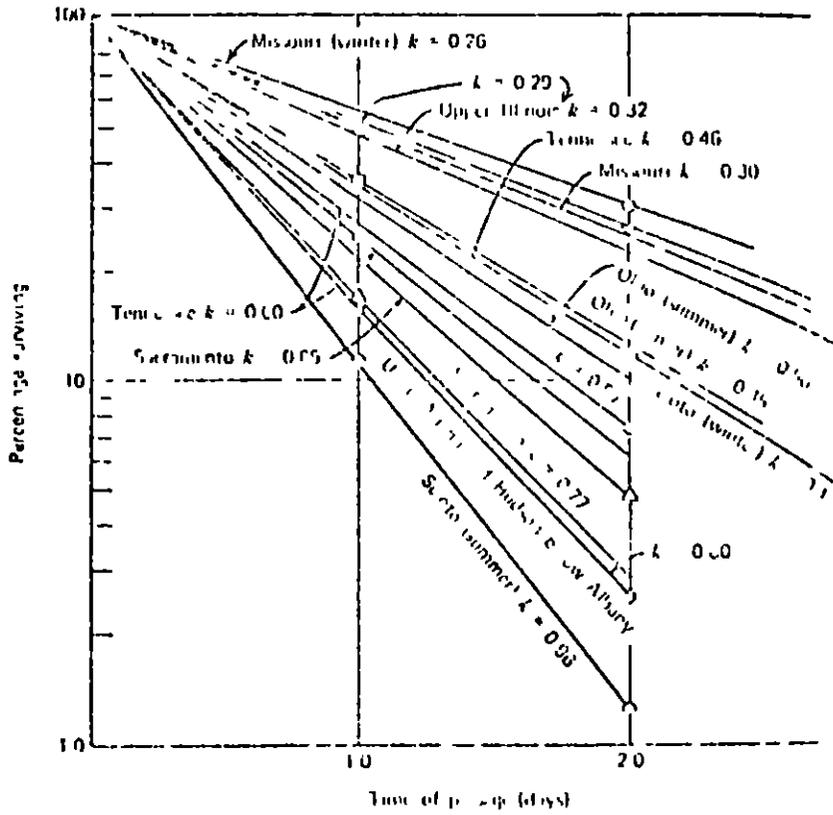
Figure 20 Fecal coliform bacteria die-off in the stream environment

probably indirectly increase the death rate by favoring the growth of secondary consumers (bacteria feeders).

6. Systematic studies on the removal of viruses in rivers are practically nonexistent.

II. Prediction of bacterial Self-Purification

A. Chick's Law

1. Bacteria die at a constant rate; that is, a given percentage of the residual population dies during each successive time unit.

2. Basic relationship

$$\frac{dB}{dt} = KB$$

This integrates to:

$$\log_{10} \frac{B}{B_o} = -Kt$$

where B = residual after any time t (day)

B_o = initial number of bacteria

K = reaction rate or death rate (day^{-1})

B/B_o = proportion of organisms that survive

$1 - B/B_o$ = proportion of organisms that die

B. Factors That Modify Chick's Law in a Stream

1. Temperature --- increase in temperature increases the death rate. See Figure 1.

2. Acidity and alkalinity --- both acidity and alkalinity increase the bacterial death rate, but under stream conditions the specific contribution of pH is not definable except when there is pronounced deviation from neutrality.

$$B = B_o(10^{-kt}) + B_o'(10^{-k't})$$

This calculation is predicated on the assumption that the residual number of bacteria at any time consists of two fractions, one resulting from the application of a death rate constant k to an initial population B_o and another from similar application of the rate k' to the initial population B_o'.

3. Phelps described some representative values for the Ohio River for the two-stage equation as shown in Table 3.

4. A review of Figure 1 and Table 3 indicates that the survival curve deviates substantially from the straight-line Chick form. The coliform group (in summer) is composed of the large fraction of 99.51 percent with a half-life of 0.64 day, and a small fraction of 0.49 percent of more resistant organisms with a half-life of over 5 days. For practical purposes this means that 99.51 percent of the coliform bacteria dieoff can be represented by the simple Chick straight-line form. Less than 0.5 percent are involved in the apparent deviation refelected in the upward turn of the survival curve.

D. Observed Death Rates

1. Some typical death rate K values are shown in Table 4.

2. The K values for large rivers are 0.5 ± 0.15 day^{-1}, for moderate size rivers the values are 0.8 ± 0.2 day^{-1}.

3. Some death rates are shown in Figure 2. It will be noted from Figure 2 that for summer conditions only a small percentage of coliforms survives after 2 days' time of passage.

-9-

3. Nutrients --- not much is known about the affect of nutrients on bacterial self-purification.

4. Sedimentation and adsorption --- both increase the death rate.

5. Presence of competitive life --- the natural biological life of polluted streams is much too rugged for the survival of organisms whose normal habitat is the shelter of the intestinal tract of man and other warm-blooded animals. In some instances coliform bacteria appear to multiply to some extent immediately after discharge into the stream.

6. These modifying factors can cause two basic changes to Chick's Law:

    (a) deviation in form

    (b) variations in observed death rates

C. Deviation in the Form of Chick's Law

1. Two principal deviations in form of the survival curve are commonly reported: an initial lag phase preceding onset of the logarithmic decline, and an afterphase of apparent decreasing death rate. In some instances during the lag phase an apparent multiplication in bacterial numbers is observed. This phenomenon is dealt with by considering the initial bacterial load as the peak and shifting the orgin of the time scale in determining the death rate to the position of the peak. The afterphase of apparent decline in death rate is shown when the semilog plot bends upward at the end of the depletion curve.

2. Mathematical formulation of a two-stage equation.

Table 4: Coliform Death Rates k Observed in Rivers
Chick's Law: $\log (B/B_o) = -kt$

River	Warm Weather	Cool Weather	Authority for Survey Data	Remarks
	Reaction Rate $k(\text{day}^{-1})$		
Ohio	0.50	0.45	Frost, Streeter et. al.	Generalized results of analysis of extensive data
Upper Illinois	0.90 0.67	0.32 0129	Hoskins et. al.	1-day decline 2-day decline
Scioto	0.96	0.46	Kehr et. al.	
Hudson	0.80		Hall, Riddick, Phelps	Freshwater reach below Albany
Upper Miami	0.80		Velz, Gannon, Kinney	Mean through reach above Dayton
Tennessee	0.46		Kittrell	1- and 2-day declines, below Knoxville
Tennessee	0.60 0.57		Kittrell	1-day decline 2-day decline (below Knoxville)
Sacramento	0.77 0.65		Kittrell	1-day decline 2-day decline (below Sacremento)
Missouri		0.30 0.26	Kittrell	1-day decline 2-day decline (below Kansas City)

Table 3: Two-Stage Equation for Bacterial
Self-Purification on the Ohio River

Parameter	Warm Weather	Cool Weather
B_o (percent)	99.51	97
k (day)	0.467	0.506
Half-life (day)	0.64	0.59
B_o' (percent)	0.49	3.0
k' (day)	0.0581	0.026
Half-life (days)	5.16	11.5

Selected References for Bacterial Self-Purification

1. Phelps, Earle B., _Stream Sanitation_, John Wiley and Sons, Inc., New York, 1944, pp. 201-221.

2. Velz, Clarence J., _Applied Stream Sanitation_, Wiley-Interscience, John Wiley and Sons, Inc , New York, 1970, pp. 234-253.

3. Wuhrmann, Karl, "Stream Purification", in Water Pollution Microbiology, edited by Ralph Mitchell, Wiley-Interscience, John Wiley and Sons, Inc., New York, 1972, pp. 133-137.

For a large stream (k = 0.5) only 10 percent survive after
2 days; for a moderate-size stream (k = 0.8) less than 3
percent survive after 2 days. However, although these sur-
vival percentages are small, it must be remembered that,
applied to the summer peak coliform bacteria loading, these
declines may result in large absolute number of survivors,
which, converted to concentrations in the diluting streamflow,
may infringe the required criteria of water quality.

PREDICTION OF THE IMPACTS
OF THERMAL DISCHARGES
ON RECEIVING STREAMS

by
L.W. Canter*

Mathematical models of varying degrees of complexity have been developed to determine the fate and persistence of heat in quiescent waters, flowing streams, estuaries, and the ocean. The ability to predict water temperatures accurately is necessary in order to determine the thermal impact of:

1. Proposed waste heat discharges.

2. Changes in the hydraulic characteristics of a water body or stream—for example, due to the construction of a dam with its resulting flow regulation.

3. Releases of water from stratified reservoirs with multilevel outlets.

4. Unusual meteorological conditions.

The following discussion presents a basic approach which can be used to solve temperature prediction problems. The material for this discussion is from two basic references (1,2).

I. Basic Principles

A. Heat Transport

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1. There are two heat transport mechanisms which occur in water--advection and dispersion or turbulent mixing. Advection is the transport of heat by the motion of a mass of water and is accomplished through ordinary streamflow, utilization of a discharge stream's kinetic energy, or water movement due to density gradients.

2. Turbulent mixing or dispersion causes heat interchange through eddy diffusion or molecular diffusion. Eddy diffusion occurs under turbulent flow, which depends on fluid velocity and channel characteristics. Mixing results from the action of small fluid masses known as eddies, which are random both in size and orientation. Molecular diffusion is that resulting from random motion of molecules. Its influence is much less than that from turbulent mixing.

B. Heat Exchange

1. Heat exchange which takes place between the water surface and the atmosphere is made up of seven mechanisms.

2. The mechanisms which are independent of water temperature are:

Q_s = Incoming short-wave solar radiation (400 to 2800 BTU/ft^2/day).

Q_a = Incoming long-wave atmospheric radiation (2400 to 3200 BTU/ft^2/day).

Q_{sr}, Q_{ar} = Portions of both short-wave and long-wave radiation which are reflected or scattered by the water surface (40 to 200 and 70 to 120 BTU/ft^2/day, respectively)

3. The mechanisms of heat transfer which are dependent on the
   surface water temperature include the following

   Q_{br} = long-wave back radiation from the water to the atmos-
   phere (2400 to 3600 BTU/ft^2/day). It is proportional to
   the fourth power of the absolute water surface temperature
   (AT_s), i.e., $Q_{br} \propto (AT_s)^4$.

   Q_c = Heat exchange due to conduction-convection (-300 to
   +400 BTU/ft^2/day), which is proportional to the wind speed
   (W) and the difference between water temperature (T_s) and
   air temperature (T_a), i.e., $Q_c \propto W(T_s-T_a)$. A positive Q_c
   indicates an energy loss.

   Q_e = Heat loss due to evaporation (2000 to 8000 BTU/ft^2/day),
   which is proportional to the product of wind speed (W) and
   the difference between the water vapor pressure in saturated
   air at the water temperature (e_s) and the water vapor pres-
   sure in the overlying air (e_a), i.e., $Q_e \propto W(e_s - e_a)$. If
   $e_a > e_s$, condensation takes place and the water body gains
   energy.

4. The algebraic sum of these surface heat exchange parameters
   is equal to the net rate of surface heat exchange. Equilibrium
   temperature is reached when this sum is zero.

II. Temperature Prediction

   A. Macro Models

   1. Macro models are those which describe or predict temperature
      regimes in a complete river or river system, lake or reservoir,

-3-

estuary, or coastal area. Such models combine heat transfer mechanisms and water movement on a continual basis with respect to time.

2. A macro model maintains an energy budget for the water body under consideration, i.e.. it maintains a heat balance of both the internal heat exchange and the heat transfer at the water surface. This heat budget may be expressed as follows:
(Rate of Heat In)-(Rate of Heat Out)+(Rate of Heat Storage)+ (Rate of Heat Exchange at Water Surface)=0

3. The rate at which heat flows into and out of the water body is determined from the flow rates and temperatures of inflowing and outflowing water. These rates require evaluation of the heat transfer mechanisms in water to define the motion of heat entrained water masses. The rate of heat storage is determined from the temperature and volume of the water body in consecutive time periods. The rate of heat exchange at the water surface is the algebraic sum of all the water-atmosphere heat exchange rates.

B. Example Problem

A power plant releases 6.41×10^9 BTU/hr. If the flow in the receiving stream is 3500 cfs, determine the temperature changes in the stream downstream from the power plant.

Solution

A. Compute the temperature rise in the stream. assuming complete mixing.

Given a design flow in the stream of 3500 cfs which in terms of lb/hr is
$$Q = 3500 \text{ cfs}) (62.4 \text{ lb/ft}^3)(3600 \text{ sec/hr})$$
$$Q = 7.86 \times 10^8 \text{ lb/hr}$$

Since 1 BTU will raise the temperature of 1 lb. of water 1°F,
$$\Delta T_r = \Delta T \text{ in river} = \frac{(6.41 \times 10^9 \text{ BTU/hr})}{(7.86 \times 10^8 \text{ lb/hr})(1 \text{ BTU/lb } ^\circ F)}$$

$$\Delta T_r = 8.2^\circ F$$

B.   Equation for computing downstream temperatures

Downstream temperatures are computed by assuming exponential temperature decay. This concept is presented mathematically as:

$$\frac{dH}{dt} = -K(T - E)$$

where $\frac{dH}{dt}$ = net rate of water surface heat exchange (BTU ft^{-2} day^{-1})

K = energy exchange coefficient (BTU ft^{-2} day^{-1} ^{o}F^{-1})

T = water surface temperature (^{o}F)

E = equilibrium temperature (^{o}F)

For a well-mixed stream, this equation can be written as.

$$\rho C_p y U \frac{\partial T}{\partial x} = -K(T_x - E)$$

where ρ = water density (62.4 lb ft^{-3})

C_p = specific heat of water (1 BTU lb^{-1} ^{o}F^{-1})

y = mean stream depth (ft)

U = mean stream velocity (ft day^{-1})

$\frac{\partial T}{\partial x}$ = longitudinal temperature gradient (^{o}F ft^{-1})

x = downstream distance (ft)

Define T_0 = temperature at x = o; then

$$T_x = (T_0 - E)e^{\left(\frac{-Kx}{\rho C_p y U}\right)} + E$$

By defining $\alpha = \frac{-Kx}{\rho C_p y U}$; then

$$\underline{T_x = (T_0 - E)e^{\alpha} + E}$$

-5-

C   Meteorologic Data

The following data are used in determining K and E.

Time Period [6 hr Intervals]	For K Wind Speed (W) (mph)	For E Net Radiation Input (H_R) [BTU ft / hr-1]	Air Temp (T_a) [°F]	Relative Humidity (%)	Water Vapor Pressure of Ambient Air (e_a) [mm Hg]
Midnight - 6 am	4 0	120	65	40	6 3
6 am - Noon	12 0	290	75	30	6 7
Noon - 6 pm	12 0	320	85	20	6 2
6 pm - Midnight	6 0	130	70	35	6 6
DAILY AVERAGE	8 5	215	74	--	6 5

D   Determination of K

The energy exchange coefficient is computed using

the following   equation

$$K = [15.7 + (0\ 26 + \beta)(bW)]$$

where W = wind speed (mph)

   b = experimental evaporation coefficient (a value of

      15 is typical.

   β = proportionality coefficient [See following table]

Range of E (°F)	β (mm Hg °F-1)
50 to 60	0 405
60 to 70	0.555
70 to 80	0.744
80 to 90	0 990

-6-

Thus, for an average daily value of K, using W = 8.5 mph:

$$K = (15.7 + [0.26 + \beta] [(15) (8.5)])$$

Using appropriate values of β for two ranges of E.

E (°F)	K(BTU ft^{-2} day^{-1} °F^{-1})
60 to 70	120
70 to 80	144

Determination of E

The equilibrium temperature is reached when the rate of change of energy at the water surface equals zero   Edinger and Geyer (2)
(2) present a method for computing E.   The method involves assuming a likely 10°F temperature range for E and by using the appropriate value for K and the given meteorological data, computing a value for E. If the computed value of E falls within the assumed range, the process is complete. However, it the computed value of E falls outside the assumed range, another range must be assumed and the process repeated until E falls within the proper limits   Thus, E is computed by a trial and error method.

For the stated meteorological conditions and computed values of K, we can determine a daily average E by the following seven steps

Step 1   Assumed range of E = 70 to 80°F

Step 2   Compute $F(K)$ for use in step 6.

$$F(K) = \frac{K - 15.7}{K}$$

As computed for an E range of 70 to 80°F, $K = 144$ BTU ft^{-2} day^{-1} $°F^{-1}$

$$\therefore F(K) = \frac{144 - 15.7}{144} = 0.891$$

Step 3.   Compute E_1 for use in step 6.

$$E_1 = \frac{H_R - 1801}{K}$$

From the meteorologic data table, $H_R = 215$ BTU ft^{-2} hr^{-1}

or in terms of days, $H_R = 5160$ BTU ft^{-2} day^{-1}

$$\therefore E_1 = \frac{5160 - 1801}{144} = 23.3$$

Step 4.   Compute E_2 for use in step 6

$$E_2 = \frac{(0.26)(T_a)}{(0.26 + \beta)}$$

From the meteorologic data table, $T_a = 74°F$, and from
the table of E range vs β, $\beta = 0.744$

$$E_2 = \frac{(0.26)(74)}{(0.26 + 0.744)} = 19.2$$

Step 5   Compute E_3 for use in step 6

$$E_3 = \frac{e_a - C(\beta)}{(0.26 + \beta)}$$

From the meteorologic data table, $e_a = 6.5$ mm Hg $C(\beta)$
is related to ranges of E as follows

Range of E (°F)	C(β) (mm Hg)
50 to 60	-11 22
60 to 70	-20 15
70 to 80	-33 30
80 to 90	-53.33

Thus for an E range of 70 to 80°F, $C(\beta) = -33.3$

$$\therefore E_3 = \frac{6.5 - (-33.3)}{(0.26 + 0.744)} = 39\ 6$$

Step 6. Compute M for use in step 7:

$$M = E_1 + \Gamma(K)\ (E_2 + E_3)$$

$$M = 23.3 + (0.891)\ (19.2 + 39\ 6) = 75\ 7$$

Step 7. Compute E using the following relationship.

$$M = E + \frac{0.051E^2}{K}$$

Inserting M and K and setting up a quadratic equation gives

$$E^2 \left(\frac{0\ 051}{144}\right) + E - 75.7 = 0$$

$$\therefore 0.000354E^2 + E - 75.7 = 0$$

Solving this equation using the quadratic formula gives:

$$E = \frac{-1 \pm [1 - (4)\ (0\ 000354)\ (-75\ 7)]^{1/2}}{2\ (0.000354)}$$

$$E = \frac{-1 \pm (1\ 10719)^{1/2}}{0.000708} = \frac{-1 \pm (1\ 05223)}{0.000708}$$

Rejecting the negative value gives

$$E = \frac{0\ 05223}{0.000708} = \underline{73.8°F}$$ (This value is acceptable because it falls within the assumed range of 70 to 80°F.)

F Compute Average Stream Velocity

Q = 3500 cfs

Given an average cross section 800 feet wide and 5 feet deep

$$U = \frac{3500\ ft^3\ sec^{-1}}{(800\ ft)\ (5\ ft)} = 0.875\ ft/sec = \underline{75,600\ ft/day}$$

G. Evaluation of α

$$\alpha = \frac{-Kx}{\rho C_p yU}$$

For x' in miles. $\alpha = \frac{-(144)\,(5280)x'}{(62.4)(1)(5)(75,600)}$

$$\alpha = \underline{-0.0322x'}$$

H. Solve for $T_{x'}$ for x' = 10, 20, ...50 miles

Assume unheated river temperature = $74^\circ F$

$\therefore T_0 = 74^\circ F + \Delta T_R = 74^\circ F + 8.2^\circ F = 82.2^\circ F$

$T_{x'} = (T_0 - E)e^{-0.0322x'} + E$

For x' = 10 miles

$T_{x'} = (82.2 - 73.8)e^{-(0.0322)(10)} + 73.8$

$T_{x'} = (8.4)e^{-0.322} + 73.8$

$T_{x'} = (8.4)(0.725) + 73.8 = \underline{79.9^\circ F}$

For y' = 20 miles

Use same value of α and replace T_0 by $T_{x'}$ for x' = 10 miles

$T_{x'} = (79.9 - 73.8)(0.725) + 73.8 - \underline{78.2^\circ F}$

For x' = 30, 40, 50 miles

Following the same procedure

30 miles, $T_{x'} = (78.2 - 73.8)(0.725) + 73.8 = 77.0^\circ F$

40 miles, $T_{x'} = 76.1^\circ F$

50 miles, $T_{x'} = 75.5^\circ F$

I These values represent the exponential temperature decay which is graphically shown on the following plot:
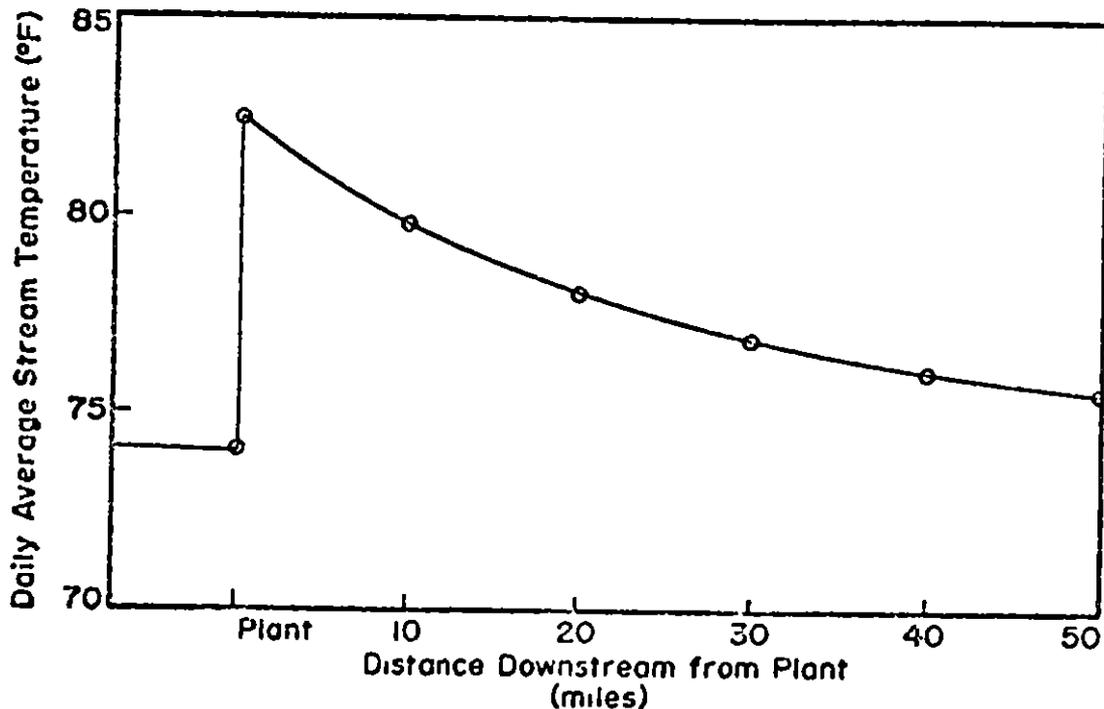
2 This graph presents an idealized picture of the downstream temperatures, since the computations were based on average daily conditions, and thus no diurnal effect is evident. It also assumes that the weather data on which K and E are based are indicative of conditions along the 50-mile stretch of the river In addition, no tributary inflows or heated discharges are accounted for in the 50 miles.

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2. Edinger, J. E., and Geyer, J. C., "Heat Exchange in the Environment", Publication No. 65-902, Edison Electric Institute, New York New York, June, 1965.

CHEMICAL/BIOLOGICAL/ENVIRONMENTAL ASPECTS
OF SOLID WASTES MANAGEMENT

by

L.W. Canter*

Concern for solid wastes management has reached national proportions only recently. As a result, considerable attention is currently being addressed to this problem at local, State and Federal levels. This discussion is focused on the chemical, biological and environmental considerations in solid wastes disposal following collection and transport. To be included herein is a summary of Federal legislation, solid wastes quantities and composition, and relevant aspects of solid wastes disposal by sanitary landfills and incineration.

I. Recent History of Federal Solid Wastes Activities

    A. Pre - 1965

        Prior to 1965 Federal activities housed in various functions within the Public Health Service.

    B. 1965 - 70

        1. In 1965 the Solid Waste Disposal Act (PL 89-272) was passed (Oct. 20).

            a), Bureau of Solid Waste Management formed

            b), National attention focused on the problem

        2. Need for passage of the Act was recognized to include the following.

            a) increasing population

            b) increasing per capita generation of solid wastes

            c) urbanization

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d). urban renewal

e)| problems csused by poor disposal

f)| economic loss resulting from failure to salvage and reuse materials

C. 1970 (+)

1. In 1970 the Resource Recovery Act (PL 91-512) was passed (Oct. 26).

   a) Emphasis shifted to recycling and recovery of solid wastes

   b) BSWM shifted to Environmental Protection Agency in December, 1970.

2. Lot of emphasis on:

   a) Recovery methods

   b) Regional planning

   c) Research and development

II. Solid Wastes Quantities and Composition

A. Quantities

1. 1969 estimate of quantities shown in Table 1. Total annual production estimated to be 4.34 billion tons.

2. Production rate on total basis is 119 lb/person/day.

3. Production rate on household, commercial and institutional basis is 5.32 lb/person/day.

   a) Measured in 1968 survey

   b) Increasing at rate of 4%/year

   c) 1959: 3.9 lb/person/day
      1920: 2.75 lb/person/day

4. General disposal practices for the 5.32 lb/person/day.

   a) 8% to approximately 300 municipal incinerators. Only about 30% have adequate air pollution control devices.

   b) 90% plus goes to some 12,000 to 14,000 land disposal sites.

      1) 6% of these sites can be considered as sanitary landfills (daily cover, no open burnings, no water pollution)

2) 94% no more than open dumps.

   c) 2% to hog feeding and composting.

   d) Small percent dumped at sea (5×10^6 tons/yr.).

B. Nomenclature

   See Table 2.

C. Composition

   1. Unit weights are shown in Table 3.

   2. Categories of refuse according to physical composition.

      --paper, wood, plastics, glass, rags, etc.

   3. Categories of refuse according to chemical characteristics·

      --moisture (%), % volatiles, '· ash, BTU/lb., and C/N ratio.

   4. Categories of refuse according to chemical elements.

      --C, H, O, N, S, inerts

   5. Data on physical composition shown in Table 4.

   6. Data on chemical composition shown in Table 5.

III. Sanitary Landfills

   A. Definition

      Sanitary landfill is a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles or engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary.

   B. Land Requirements

      1. Data required

         a) Refuse production (population and unit production)

         b) Compaction ratio

         c) Density of refuse

         d) Anticipated settling within fill

2. Calculations

   a) Volume requirements

   $$V = \frac{R}{D} \left(1 - \frac{P}{100}\right) + Cv$$

   where:

   V = volume required for refuse disposed, yd^3 per capita per year.

   R = amount of refuse handled at sanitary landfill (lb/cap-yr.)

   D = average density of refuse (lb/yd^3)

   P = refuse volume reduction from compaction (%)

   CV = volume of cover material required (yd^3/cap-yr)

   = 1 part cover to 4 parts refuse

   b) Area requirements

   $$A = \frac{27}{(d)} \frac{(V)}{43,560} \frac{(N)}{}$$

   where:

   A = land needed (acres)

   d = compacted depth of refuse (ft)

   N = population

3. Rules-of-thumb

   a) 2 yd^3/person/yr

   b) 1.25 ac-ft/1000 persons/yr

   c) 2 acres/10,000 persons/yr (6 ft. lift)

C. Methods of Sanitary Landfilling

1. Area method

   a) Deposit refuse at bottom of slope for best compaction and control of blowing litter.

b) Spread and compact refuse against slope of previous lift, progressing horizontally along slope.

c) Cover with earth excavated from adjacent area or with cover from offsite borrow area.

d) Cover final lift to minimum depth of 2 feet.

2. Trench method

a) Lay out trenches perpendicular to access road, beginning fill at road.

b) Leave divider of about two feet of undisturbed earth between trenches.

c) Dump the refuse, preferably at the bottom of the trench, and spread and compact in layers.

d) Proportion width of trench to size of operation

e) Obtaining cover material

1) Progressive trench excavation, obtaining cover material just ahead of operation.

2) Excavation of an adjacent trench

3) Excavation of one or more complete trenches and stock-piling of cover material.

D. Bacterial Decomposition of Solid Wastes

1. Bacteria perform the same function in landfills as they do in biological sewage treatment processes such as activated sludge units and trickling filters; i.e., they degrade organic material.

2. A typical representation of the aerobic bacterial composition of organic material in indicated in Equation 1.

$$6 \ (CH_2O)_x \ + \ 5O_2 \longrightarrow (CH_2O)_x \ + \ 5CO_2$$
$$+ \ 5 \ H_2O \ + \ energy \qquad \qquad Eq. \ 1$$
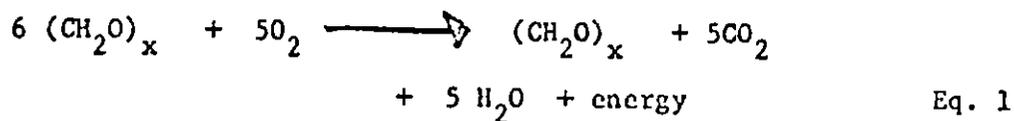
3. As denoted in Equation 1 organic material, represented as carbohydrates $[6(CH_2O)_x]$, is converted into bacterial cells $(CH_2O)_x$, carbon dioxide, and water. The released energy is used in the synthesis of the new cells. Dissolved oxygen is used as the electron acceptor and, as a result, is consumed in the process. Although not shown in Equation 1, soluble inorganic materials such

as nitrates, phosphates and sulfates are released to solution from the organic material.

4. When the dissolved oxygen is depleted, anaerobic bacterial degradation will occur. Under anaerobic conditions, conversion of organic material to bacterial cells occurs by a two-step process: organic acid production and methane production. Organic acid production is represented by Equation 3, and methane production by Equation 4.

$$5 \ (CH_2O)_x \longrightarrow (CH_2O)_x + 2CH_3COOH + energy$$

Eq. 3.

$$2 \ 1/2 \ CH_3COOH \longrightarrow (CH_2O)_x + 2 \ CH_4 + 2CO_2 + energy$$

Eq. 4.
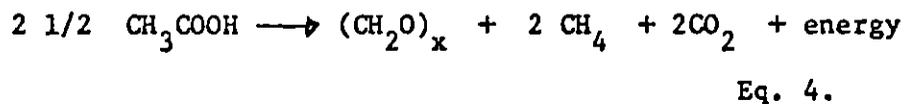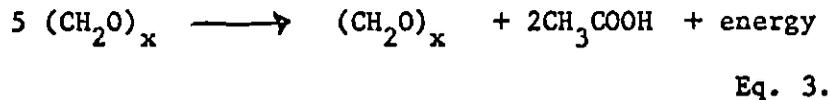
5. Organic acids can be oxidized to carbon dioxide and water in the presence of dissolved oxygen.

E. Environmental Fate of Materials in Landfills

1. Metals (approximately 7% of total)

a) Remain in landfill as inert or relatively inert compounds unless fill eroded by surface runoff: Uncombined metals; Al_2O_3; $Al(OH_3)$; FeO; FeO_2; $Fe(OH)_2$; $Fe(OHO_3)$; CrO_2; Cr_2O_3; $Cr(OH)_2$; Cu_2O; CuO; $Cu(OH)_2$; SnO; ZnO; $Zn(OH)_2$; V_2O_2; Be; BeO, NiO; Ni_2O_3, $Ni(OH)_2$; CdO; $Cd_2)$, $Cd(OH)_2$; PbO; Pb_2O_3; Pb_3O_4; Pb_2O; Se; SeO_2; Hg; HgO; TiO_2; MgO; $Mg(OH)_2$; $Ca(OH)_2$; $CaCO_3$.

b) May leach to groudwater. Ca and Mg sulfates; Fe, Ca, and Mg bicarbonates; CO_2; also oxides of Sn, Zn, Cu in acid water.

c) Escape to atmosphere: essentially none.

2. Cloth – natural and synthetic fibers (approximately 4% of total)

a) Remain in landfill as inert or relatively inert materials:

1) Materials fabricated of synthetic fabrics

2) Oxidized and reduced minerals in "natural" fibers.

23

b) Remain in landfill by incorporation in to microbial protoplasm. NH_4 +, reduced sulfur compounds, C, P, K.

c) May leach out to groundwater: CO_2; aldehydes, ketones; organic acids; sulfates; phosphates; NH_4+; NO_2-; NO_3-.

d) Escape to atmosphere: CO_2; CH_4, volatile short-chain fatty acids; N_2, NH_3, h_2S, mercaptans.

3. Plastics (approximately 1.9% of total) -- essentially inert in landfill.

4. Leather (approxiamtely 1% of total).

   a) May leach out to groundwater; CO_2; aldehydes, ketones, organic acids; sulfates; phosphates, NH_4+; NO_2-; NO_3-.

   b) Remain in landfill by incorporation into microgial protoplasm- NH_4+, reduced sulfur compounds; C, P, K.

   c) May escape into atmosphere: CO_2, CH_4; volatile short-chain fatty acids; N_2; Nh_3; H_2S, mercaptans.

5. Rubber - natural and synthetic (approximately 1.1% of total)

   a) Synthetic rubber is essentially inert.

   b) Natural rubber breaks down extremely slow.

6. Glass (approximately 8% of total) -- inert in landfill.

7. Wood (approximately 2% of total)

   a) May leach to groundwater: CO_2; aldehydes, ketones, organic acids, phenol; NH_2+, NO_2-; NO_3-.

   b) Remain in landfill through incorporation into microbial protoplasm. NH_4+; C; P; K.

   c) May escape into atmosphere: CO_2; CH_4; volatile short-chain fatty acids, N_2; NH_3.

8. Garbage (approximately 15.5% of total)

   a) Possible leachates to groundwater See WOOD (above), plus sulfates, phosphates, and carbonates.

   b) See Item b, WOOD (above).

   c) May escape into atmosphere: CO_2; CH_4, volatile short-chain fatty acids; H_2S; mercaptans; N_2, NH_3.

9. Paper (approximately 51.5% of total)

   a) May leach to groundwater: CO_2; aldehydes; organic acids; phenol; NH_4^+; NO_2; NO_3^-.

   b) Remain in landfill through incorporation into microbial proto-plasm, NH_4^+; C, P, S.

   c) May escape into atmosphere: CO_2; CH_4; volatile short-chain fatty acids, H_2S, mercaptans, N_2; NH_3.

10. Unclassified fraction (approximately 5% of total)

   a) Relatively inert

   b) Ashes in fill may leach soluble minerals to groundwater reducing its chemical quality.

F. Costs of Landfills

   1. The cost of a sanitary landfill consists of the initial investment for land, equipment, and construction features, and the operating costs.

   2. Generally, the major portion of the initial investment is for the purchase of the land and equipment. Often a sizeable part of the initial investment for land and equipment can be recovered through the development or use of the land and the salvage value of the equipment.

   3. Wages ordinarily make up about 40-50% of the total operating cost. Equipment operations, maintenance and amortization equals 30-40%, cover material, administration, overhead, and miscella-neous amount to about 20%.

   4. The operating cost of a small operation handling less than 50,000 tons per year varies from $1.25 to approximately $5.00 per ton. The unit cost of a large landfill handling more than 50,000 tons per year will generally fall between $0.75 to $2.00 per ton.

IV. Incineration

   A. Definition

   Controlled burning of refuse in such a manner that the combustible portion is consumed to a high degree of completion with a minimum of smoke and odor.

   B. Status

   Have approximately 300 central (municipal) incinerators in the U.S. Can be feasible for population of greater than 50,000.

208

C. Incinerator Components

1. Truck scales

2. Tipping floor

3. Storage pit

4. Charging method

   a) method to move solid waste from storage area to hopper.

   b) charging hopper

   c) charging chute

5. Furnace

   a) Components: hearth, grates, ash hopper, and gate

   b) Types of furnaces:

      1) Single-chamber, cylindrical, batch-feed type

      2) Single or multiple cell, rectangular, batch-feed type

      3) Continuous-feed type

   c) Burning rates

      1) Temperatures: 1300-2000 F (average of 1700-1800F)

      2) Grate loading based on a heat release from the burning material at the rate of 300,000 BTU per hour per square foot. (50-100 lb. refuse/hr/ft^2)

   d) Types of grates

      1) travelling

      2) rocking

      3) reciprocating

      4) circular

   e) Overfire and underfire air

   f) refractory-lined and water-walled furnaces

   g) breechings and air pollution control devices

   h) stack

D. Incinerator Calculations

1. Calculation of air requirement and gas composition at zero excess air.

C

H CO_2

O O_2 H_2O

N N_2

S SO_2

inerts (O_2)

2. Calculation of effect of excess air on gas composition.

3. Temperatures calculations using enthalpics.

E. Residue from Combustion

1. Residue is all solid materials remaining after burning. It includes ashes, clinkers, tin cans, glass, rocks, and unburned organic substances.

a) 20-25% by weight of original solid wastes.

b) 10-20% by volume

c) may contain water soluble materials.

2. See Table 6 for typical chemical analysis of residue

3. Residue handling and disposal.

4. Residue quench water

a) 1000-2000 gal/ton of solid waste (without water recirculation)

b) 500-1000 gal/ton (with water recirculation)

c) quality characteristics

high pH (10-12)

TDS (3000-7000 mg/l)

hardness (600-1200 mg/l)

sulfates (200-400 mg/1)

BOD (?)

F. Air Pollution Control

    1. Particulates

        a) 10-60 lb. fly ash/ton of solid waste

        b) size distribution

            10% by weight $< 2\mu$

            30% by weight $< 10\mu$

            50% by weight $< 30\mu$

    2. Summary of uses of particulate collectors in municipal incinerators

Type	Status	Eff. (% by wt.)	Installation Cost
Settling, Chamber	used up to 1960	10-34	
Cyclones & multiple cyclones	used in 20% of incinerators built since 1957	60-65 up to as high as 70-80	$0.12 - 0.25/acfm
Wet Scrubbers	used in 20% of incinerators built since 1957	94 to 96 (water requirement is 5-15 gal per 1000 acfm	$0.25 - 1.25/acfm
ESP (operated at about 500° F)	some being used since about 1968	96 - 99+	$0.85-1.45/acfm
Fabric Filters	just coming into use	99+	$0.75 = 1.50/acfm

    3. Gases

        a) control through proper incineration operations

        b) scrubbers

G. Environmental Fate of Materials in Incineration

302

1. Metals (approximately 7% of total)

    a) Appear in metallic form in residue to reclamation or land-fill; Fe, Al, Pb, Zn, Cu.

    b) Appear as relatively inert compounds in ash to landfill
        FeO, Fe_2O_3; Al_2O_3; SiO_3, CrO_2, CrO_3; Cu_wO; CuO, ZnO; SnO;
        V_2O_2, V_2O_3; V_2O_4, $NiO1$ Ni_2O, Ni_3O_4, CdO, Cd_2O; PbO; PbO_2;
        Pb_3O, Pb_2O_3; Pb_2O; SeO, HgO; TiO_2; Ti_2O_3; MgO, CaO.

    c) May appear as particulate matter in stack discharges
        (see b above)

    d) May appear as vaporized metal in stack discharges: Al;
        Be; Zn; Hg, Se, Pb; Cd.

    e) Appear as gases in stack discharges: CO_2; CO, SO_2; SO_3.

    f) Appear in stack discharge as by-products of incineration
        process. N-oxides.

2. Cloth - natural and synthetic fibers (approximately 4% of total)

    a) Appear as gases in discharge: CO; CO_2; SO_2; S_2O_3; SO_3.

    b) May appear in stack discharge as products of synthesis and in-
        complete combustion: aldehydes; ketones; low molecular
        weight hydrocarbons, HCl chlorinated hydrocarbons; poly-
        neuclear hydrocarbons.

    c) Appear in stack discharge as by-products of incineration
        process: N-oxides.

    d) May appear as particulate matter in stack discharge.

3. Plastice (approximately 1.9% of total)

    a) May appear in stack discharge as products of synthesis and
        incomplete combustion; HCl; halides, aldehydes, low molecular
        weight hydrocarbons, low molecular weight polunuclears and
        aromatic hydrocarbons.

    b) Appear as gases in stack discharge: CO, CO_2; SO_2 S_2O_3; SO_3

    c) May appear as vaporized plactic in stack discharge

    d) May appear as particulate matter in stack discharge.

    e) Appear in stack discharge as by-products of incineration pro-
        cess: N-oxides.

4. Leather (approximately 1% of total)

    a) Stack discharge: See Items a, <u>Plastics</u> Above.

    b) Appear in stack discharges as by-products of incineration:
        N-oxides.

5. Rubber - natural and synthetic (approximately 1.1% of total)

    a) Stack discharge same as for <u>Plastics</u> (items a, b and c)

    b) Appear in stack discharges as by-products of incineration
        process: N-oxides.

6. ...... (approximately 8% of total)

    --appears as inert material in ash to landfill.

7. Wood (approximately 2% of total)

    e) Appear in stack discharge as combustion products:
        CO, CO_2.

    b) Appear in stack discharge as by-products of incineration:
        N-oxides.

    c) May appear in stack discharge as products of synthesis or
        of incomplete combustion: low molecular weight hydrocarbons;
        low molecular weight aromatic and aliphatic hydrocarbons;
        polynuclear hydrocarbons; phenols.

    d) May appear as particulate matter in stack discharge.

    e) Appear in ash for disposal to landfill: K_2O; KOH; phosphates.

8. Garbage (approximately 15.5% of total)

    --Stack discharges same as for <u>Wood</u> (Items a, b, c and d)
    plus aldehydes, ketones and acrolein.

9. Paper (approximately 51.5% of total)

    a) Appear in stack discharge as combustion products: CO, CO_2.

    b) Appear in stack discharge as by-products of incineration:
        N-oxides.

    c) May appear in stack discharge as products of incomplete com-
        bustion or synthesis: low molecular weight hydrocarbons;
        low molecular weight aromatic and polynuclear hydrocarbons,
        phenols.

300

d) May appear as particulate matter in stack discharge.

10. Unclassified fraction (approximately 5% of total)

   a) Appears as inert material in ash to landfill.

H. Incinerator Costs

   1. Construction costs

      a) Includes the following:

         --refuse handling and storage facilities; furnaces and
         chambers for burning the refuse, chimneys, facilities
         for handling residues and gaseous products; building;
         and grounds.

      b) Construction costs have been increasing

         1) 1950 -- $2000/ton

         2) 1960 -- $4500/ton

         3) 1966 -- $6150/ton (average of 170 municipal incinerators)

   2. Operational costs

      a) Vary from $3 to $7/ton

      b) 1968 National Survey provided operational costs for 78
         municipal incinerators.

         -- average cost $5/ton

         73% of the plants had costs less than $5/ton

         4 of the 78 plants had costs greater than $10/ton

V. SELECTED REFERENCES

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TABLE 1: 1969 SOLID WASTE PRODUCTION

Category	Annual Production (tons)
Household, commercial and institutional	250×10^6 *
Industrial wastes	110×10^6
Agricultural wastes**	2280×10^6
Mineral wastes	1700×10^6
TOTAL --	4340×10^6

*190×10^6 tons collected and disposed of by public and private collectors.

**Includes crop residues and animal wastes.

TABLE 2

REFUSE MATERIALS BY KIND, COMPOSITION, AND SOURCES

	Kind	Composition	Sources
Refuse	Garbage	Wastes from preparation, cooking, and serving of food, market wastes, wastes from handling, storage, and sale of produce	Households, restaurants, institutions, stores, markets
	Rubbish	Combustible: paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, wood furniture, bedding, dunnage	
		Noncombustible: metals, tin cans, metal furniture, dirt, glass, crockery, minerals	
	Ashes	Residue from fires used for cooking and heating and from on-site incineration	
	Street Refuse	Sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles	Streets, sidewalks, alleys, vacant lots
	Dead Animals	Cats, dogs, horses, cows	
	Abandoned Vehicles	Unwanted cars and trucks left on public property	
	Industrial Wastes	Food processing wastes, boiler house cinders, lumber scraps, metal scraps, shavings	Factories, power plants
	Demolition Wastes	Lumber, pipes, brick, masonry, and other construction materials from razed buildings and other structures	Demolition sites to be used for new buildings, renewal projects, expressways
	Construction Wastes	Scrap lumber, pipe, other construction materials	New construction, remodeling
	Special Wastes	Hazardous solids and liquids explosives, pathological wastes, radioactive materials	Households, hotels, hospitals, institutions, stores, industry
	Sewage Treatment Residue	Solids from coarse screening and from grit chambers, septic tank sludge	Sewage treatment plants, septic tanks

TABLE 3:   UNIT WEIGHTS ON REFUSE COMPONENTS

Category	lb/yd^3	
Garbage	800 - 1500	Avg. 950
Ashes	1150 - 1400	Avg. 1250
Household refuse	300 - 600	Avg. 400
Rubbish and ashes	400 - 1000	Avg. 700
Noncombustible rubbish	400 - 600	Avg. 500
All refuse together	300 - 700	Avg. 350

TABLE 4: PHYSICAL COMPOSITION

Component	% by wt. (wet basis)
Metal products	8 - 11
Glass products	8 - 11
Paper products	40 - 54
Food wastes	10 - 26
Yard wastes	3 - 80
Wood	3 - 70
Plastic products	1 - 20
Rubber, leather, cloth & synthetics	1 - 20
Dirt, ash, rocks, & other inerts	1 - 50

TABLE 5: CHEMICAL COMPOSITION

Element	% by wt. (wet basis)
Moisture	15.0 - 50.0
C	15.0 - 30.0
H	2.0 - 5.0
O	12.0 - 24.0
N	0.2 - 1.0
S	0.02 - 0.1
Ash & metal	10.0 - 25.0

TABLE 6.   TYPICAL CHEMICAL ANALYSES OF RESIDUE

Test	Range %	Desirable Limit %
Moisture	10-40	less than 20
Non-Combustible	50-100	100
Volatile Material	0-50	0
Water Soluble	1-8	minimum
Ether Soluble	0-5	0
Nitrogen	0-2	0
Iron	5-20	-
Silica	30-70	-
Calorific Value	0-5000	0
Protein	0-1	0
Phosphorus	0-0.5	0
Carbon	0-20	-
Hydrogen	0-5	-

HISTORICAL AND AESTHETIC IMPACTS

I. Categories of impact.

    A. Historical factors.

        1. Archeological artifacts.

        2. Structures with intrinsic historical value.

        3. Landscapes with historical value.

        4. Ways of life with historical value.

    B. Aesthetic factors.

        1. A "sense of place".

        2. Beauty, cultural preference, and psychological well-being.

II. A case study. a proposed hydroelectric power facility in the Bovec valley, Slovenia, Yugoslavia.

    A. Conflicting economic needs and historica/aesthetic values.

    B. The role of citizen participation.

    C. Differing scales of concern: local, regional, national.

III. Assessment methodologies.

    A. Archeological sampling and monitoring of construction activities.

    B. Local and regional historical studies.

    C. Surveys of items and places of historical/aesthetic value, including a classification of items and a listing of priorities for preservation.

    D. Attitude surveys

IV. Approaches to resolving conflicts.

    A. Defining priorities for preservation.

    B. Defining systems of compensation.

    C. Defining frameworks for reaching accomodation.

INTERNATIONAL IMPLICATIONS

I. The diffusion of environmental consequences.

    A. Examples.

        1. Water pollution--the Rhine, the Adriatic, pesticides and fish in the sea, etc.

        2. Air pollution--radioactive wastes, long-term climatic change.

    B. The Stockholm Conference: an attempt to arrive at international understandings.

II. The diffusion of technologies having environmental impact.

    A. The historical spread of industry and mining.

    B. The diffusion of control technologies.

    C. The possibilities for environmental transformation--the example of desalination.

III. International aims and national interests.

    A. Environmental conservation--a luxury? (the case of DDT)

    B. Exporting environmental problems.

IV. Possibilities for international cooperation.

    A. Satellite sensing of environmental resources and changes.

    B. Sharing water resources.

    C. Controlling oil spills.

    D. Technological transfer.

PREDICTION AND ASSESSMENT OF

IMPACTS ON THE NOISE ENVIRONMENT

by

L. W. Canter*

I. Introduction

    A. Lxamples of projects causing noise impacts

        1. Construction of power plants, highways, airports and pipelines.

        2. Operation of airports, highways and compressor stations.

    B. Basic steps in prediction and assessment of noise impacts

        1. Identify the noise levels for the alternatives for a project need during both construction and operational phases. This may involve a literature review, analysis of other EIS's on similar types of alternatives, or field measurements at existing installations of similar types.

        2. Determine the existing noise levels for the project area. May involve field measurements or determination of land uses in the area. Note any unique noise sources in the area, or any unique places where noise levels must be minimized.

        3. Procure applicable noise standards and criteria.

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4. Predict the anticipated noise levels (microscale impact) in the area of the project for each alternative during both the construction and operational phases. Compare the predicted levels with the applicable standards or criteria.

5. If standards or criteria are exceeded, consider noise control methods.

II. Basic Information on Noise

A. Definition

1. Noise is unwanted sound. It is sound in the wrong place at the wrong time.

2. Any sound which is undesirable because it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying. (1)

3. Noise is discordant sound resulting from non-periodic vibrations in air. (2)

4. The definition of noise as unwanted sound implies that it has an adverse effect on human beings and their environment, including land, structures, and domestic animals. Noise also affects natural wildlife and ecological systems.

B. The Nature of Sound (3)

1. Sound is a mechanical energy from a vibrating surface, transmitted by a cyclic series of compressions and rare-factions of the molecules of the material through which it passes.

2. Sound is transmitted through gases, liquids and solids.

3. A vibrating source producing sound has some total power, and the sound results in a sound pressure which alternately rises to a maximum pressure of compression and drops to a minimum pressure of rarefaction.

4. Values of sound power or sound pressure do not provide a practical unit for sound or noise measurement for two reasons.

   (a) There is a tremendous range of sound power and sound pressures produced. Expressed in microbars, one-millionth of 1 atmosphere of pressure, the range is from 0.0002 microbar (μbar), the minimum sound pressure of a healthy young human ear can detect, to 10,000 μbars for peak noises within 100 ft. from large jet and rocket propulsion devices.

   (b) Our ears do not respond linearly to increases in sound pressure. The nonlinear response is essentially logarithmic. The human ear can discern without pain sounds ranging from a threshold to sounds 10^{12} times as intense.(2)

5. The number of compressions and rarefactions of the air molecule density in a unit of time associated with a sound wave is described as its frequency. The unit of time is usually one second, and the term "Hertz" (after an early investigator of the physics of sound) is used to designate the number of cycles per second. Again, the human ear and that of most animals has a wide range of response. Humans can identify sounds with frequencies from about 16 Hz to 20,000 Hz. (2)

312

C. Sound and Noise Measurement (3)

1. The measurement needs are met by a term, sound pressure
    level (SPL), expressed as a logarithmic ratio to a
    reference level and stated in a dimensionless unit of
    power, the decibel (dB). The reference level is 0 0002
    μbar, the threshold of human hearing.

    $$SPL = 20 \log_{10} \left(\frac{P}{P_0} \right)$$

    where SPL = sound pressure level expressed in dB

    P = sound pressure (μbar)

    Po = reference pressure (0.0002 μbar)

2. Some example calculations

    At P = 0.0002,

    $dB = 20 \log \frac{0.0002}{0.0002} = 20 \log 1 = 20 \ (0) = 0$

    At P = 0.2

    $dB = 20 \log \frac{0.2}{0.0002} = 20 \log 1,000 = 20 \ (3) = 60$

    At P = 20

    $dB = 20 \log \frac{20}{0.0002} = 20 \log 100,000 = 20 \ (5) = 100$

    At P = 20,000

    $dB = 20 \log \frac{20,000}{0.0002} = 20 \log 100,000,000 = 20 \ (8) = 160$

3. Table 1 contains a summary of various sound pressures and
    the corresponding decibel levels, with examples of recognized
    sources of noise being cited.

4. As the SPL-decibel scale is logarithmic, decibel values are
    not additive. For example, and SPL of 74 dB from one source
    superimposed on one of 75 dB does not result in 149 dB.

Table 1: THE DECIBEL SCALE OF SPL, WITH SOUND
PRESSURES IN MICROBARS, AND RECOGNIZED
SOURCES OF NOISE IN OUR DAILY EXPERIENCES

Sound Pressure μbar	dB	Example
0.0002	0	Threshold of Hearing
0.00063	10	
0.002	20	Studio for sound pictures
0.0063	30	Studio for speech broadcasting
0.02	40	Very Quiet room
0.063	50	Residence
0.2	60	Conventional speech
0.63	70	Street traffic at 100 ft.
1.0	74	Passing automobile at 20 feet
2.0	80	Light trucks at 20 ft.
6.3	90	Subway at 20 ft.
20	100	Looms in textile mill
63	110	Loud motorcycle at 20 ft.
200	120	Peak level from rock and roll band
2,000	140	Jet plane on the ground at 20 ft.

An SPL of 77.6 dB results. To determine the total effect, it is necessary to convert decibel readings to intensity ratios, then reconvert the new sum back to a decibel value To aid in this process, Table 2 is provided for determining the cumulative decibel values of two or more known observations on individual sources. The value in the difference column in Table 2 is always added to the highest of the two decibel values being handled.

5. In most noise considerations, the A - weighted sound level is used. This level is explained as follows. The ear does not respond equally to sounds of all frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are dB. A popular method of indicating the units, dBA, is frequently used. The A-weighted sound level is also called the noise level. Sound level meters have an A-weighting network for measuring A-weighted sound level.

D. Some General Facts on Noise Abatement

1. The "Noise Control Act of 1972" is the basic Federal legislation for noise emissions from a broad range of sources. (4)

Table 2:   DETERMINING THE CUMULATIVE
           DECIBEL SPL WHEN THE DIFFERENCES
           BETWEEN TWO OR MORE LEVELS ARE
           KNOWN

Difference between levels, dB	No. of dB to be added to higher level
0	3.0
1	2.6
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
10	0.4
12	0.3
14	0.2
16	0.1

2   The basic needs for the Noise Control Act of 1972 were

cited in the Act as follows:

> (1) that inadequately controlled noise presents
>
> a growing danger to the health and welfare of
>
> the Nation's population, particularly in
>
> urban areas,
>
> (2) that the major sources of noise include trans-
>
> portation vehicles and equipment, machinery,
>
> appliances, and other products in commerce, and
>
> (3) that, while primary responsibility for control
>
> of noise rests with State and local governments,
>
> Federal action is essential to deal with major
>
> noise sources in commerce control of which re-
>
> quire national uniformity of treatment.

3. The policy of the U.S. is to promote an environment for all

Americans free from noise that jeopardizes their health or

welfare.

4. Predictions indicate that the noise in our environment is

increasing by as much as 1 dB per year, or 10 dB per decade.

(1) Some reasons for these increases include.

> (a) growth in number of miles of urban freeway.
>
> (b) increase in commercial air traffic, and shift in
>
> aircraft from propeller-type to jet-type.
>
> (c) increase in construction activity.
>
> (d) increase in noisy devices such as power lawnmowers
>
> and motorcycles.

5. An estimated 16 million persons are presently exposed to aircraft noise levels with effects ranging from moderate to very severe. (5)

6. Hearing losses in the overall population are estimated in Table 3. (1)

III. Anticipated Noise Levels (Step 1)

A. Construction Equipment and Operations (1)

1. Construction site categories can be considered to be comprised of four major types:

   (a) Domestic housing - including residences for one to several families.

   (b) Nonresidential buildings - including offices, public buildings, hotels, hospitals, schools.

   (c) Industrial - including industrial buildings, religious and recreational centers, stores, service and repair facilities.

   (d) Public works - including roads, streets, water mains, sewers.

   Noise from construction of such major civil works as dams and bridges affects relatively few people (other than those employed at or near such construction sites).

2. Noise from a construction site varies as to the particular operation in progress, there are five consecutive phases.

   (a) Ground clearing - including demolition and removal of prior structures, trees, rocks.

-9-

317

TABLE 3· Hearing Loss (Moderate to Profound) in U.S.

Age Range	Population Totals (in thousands)	Loss of Hearing Totals (thousands)	Noise-Associated Hearing Loss (thousands)
0-5	17,000	850	?
5-10	20,000	1,000- 1,400	*200
10-18	32,500	650- 975	**150
18-65	113,000	2,260	2,000 (Approx)
Over 65	20,000	4,000	400-600
TOTALS	202,500	8,700-11,135	2,750-2,950

* Most common cause is explosions from toy caps (20% sensory-neural hearing loss).

** Firearms and toy caps (based on approximately 20% sensory-neural hearing loss).

      (b)   Excavation.

      (c)   Placing foundations - including reconditioning old roadbeds, compacting trench floors.

      (d)   Erection - including framing, placing of walls, floors, windows, pipe installation.

      (e)   Finishing - including filling, paving, cleanup.

3.   Table 4 shows typical energy equivalent noise levels at construction sites. Energy equivalent noise level (Leq) refers to the equivalent steady noise level which in a stated period of time would contain the same noise energy as the time-varying noise during the same time period (6) The maximum levels range from 77 to 89 dBA for all categories and have an average value of approximately 85 dBA. The minimum values for all categories have a wider range, extending from 65 to 88 dBA, and have an average value of 78 dBA. The table also shows that the initial ground clearing and excavation phases generally are the noisiest, that the intermediate foundation placement and erection phases are somewhat quieter, and that the final finishing phase tends to produce considerable noise annoyance.

4.   Noise levels observed 50 ft. from construction equipment are shown in Table 5. These levels range from 72 to 96 dBA for earthmoving equipment, from 75 to 88 dBA for materials handling equipment, and from 70 to 87 dBA for stationary equipment.

B.   Examples of Noise Levels from Project Operation

1.   Examples to be considered include highway vehicles, aircraft,

TABLE 4   Typical Ranges of Energy Equivalent Noise Levels, L_{eq} in dbA, at Construction Sites

	Domestic Housing		Office Building, Hotel, Hospital, School, Public Works		Industrial Parking Garage, Religious Amusement and Recreations, Store, Service Station		Public Works Roads & High-ways, Sewers, and Trenches	
	I	II	I	II	I	II	I	II
Ground Clearing	83	83	84	84	84	83	84	84
Exaavation	88	75	89	79	89	71	88	78
Foundations	81	81	78	78	77	77	88	88
Erection	81	65	87	75	84	72	79	78
Finishing	88	72	89	75	89	74	84	84

I - All pertinent equipment present at site.

II - Minimum required equipment present at site.

TABLE 5. Construction Equipment Noise Ranges

		NOISE LEVEL (dBA) AT 50 FT					
		60	70	80	90	100	110
EARTH MOVING	COMPACTERS (ROLLERS)		■				
	FRONT LOADERS		▬▬▬				
	BACKHOES		▬▬▬▬▬▬				
	TRACTORS		▬▬▬▬▬▬				
	SCRAPERS, GRADERS		▬▬▬▬				
	PAVERS		▬				
	TRUCKS		▬▬▬				
MATERIALS HANDLING	CONCRETE MIXERS		▬▬▬▬				
	CONCRETE PUMPS		▬				
	CRANES (MOVABLE)		▬▬▬				
	CRANES (DERRICK)		▬				
STATIONARY	PUMPS	■					
	GENERATORS	▬▬▬					
	COMPRESSORS	▬▬▬					
IMPACT EQUIPMENT	PNEUMATIC WRENCHES		▬▬				
	JACK HAMMERS AND ROCK DRILLS		▬▬▬▬▬				
	IMPACT PILE DRIVERS (PEAKS)		▬▬▬				
OTHER	VIBRATOR	▬▬▬					
	SAWS	▬▬▬					

EQUIPMENT POWERED BY INTERNAL COMBUSTION ENGINES

Note   Based on Limited Available Data Samples

-13-

3.0

rail systems, recreation vehicles, internal combustion
engines, industrial machinery, building equipment, and
home appliances.

2. The noise levels produced by highway vehicles can be attributed
to the following three major noise generating systems (7)

   (a) rolling stock, tires and gearing

   (b) propulsion system: engine and related accessories

   (c) aerodynamic and body

3. The noise levels produced by highway vehicles are generally
dependent upon vehicle speed, as illustrated for a number of
different vehicle types in Figure 1.

4. General Characteristics of highway vehicles are shown in
Figure 2. (7)

5. General characteristics of commercial aircraft are shown in
Figure 3, V/STOL aircraft in Figure 4, and general aviation
aircraft in Figure 5.

6. General characteristics of rail systems are shown in Figure 6.

7. General characteristics of recreation vehicles are shown in
Figure 7.

8. General characteristics of devices powered by internal
combustion engines are shown in Figure 8.

9. Typical ranges of noise levels from industrial machinery,
equipment and processes are shown in Table 6.

10. Typical ranges of building equipment noise levels are in
Table 7.

11. Typical noise levels of home appliances are in Table 8.

Figure 1: Single Vehicle Noise Output as a Function of Vehicle Speed

Highway Vehicles

| Automobiles | Trucks | Utility & Maintenance | Buses |

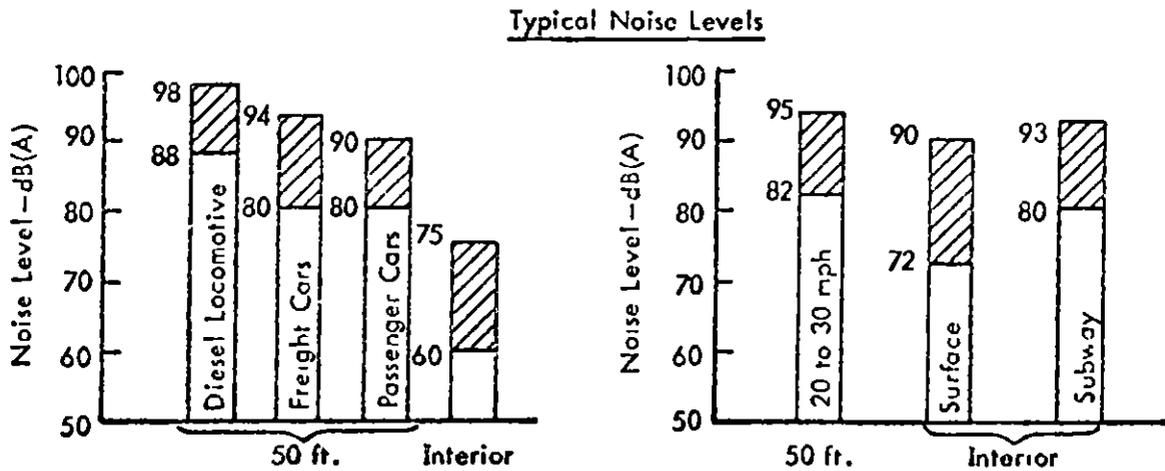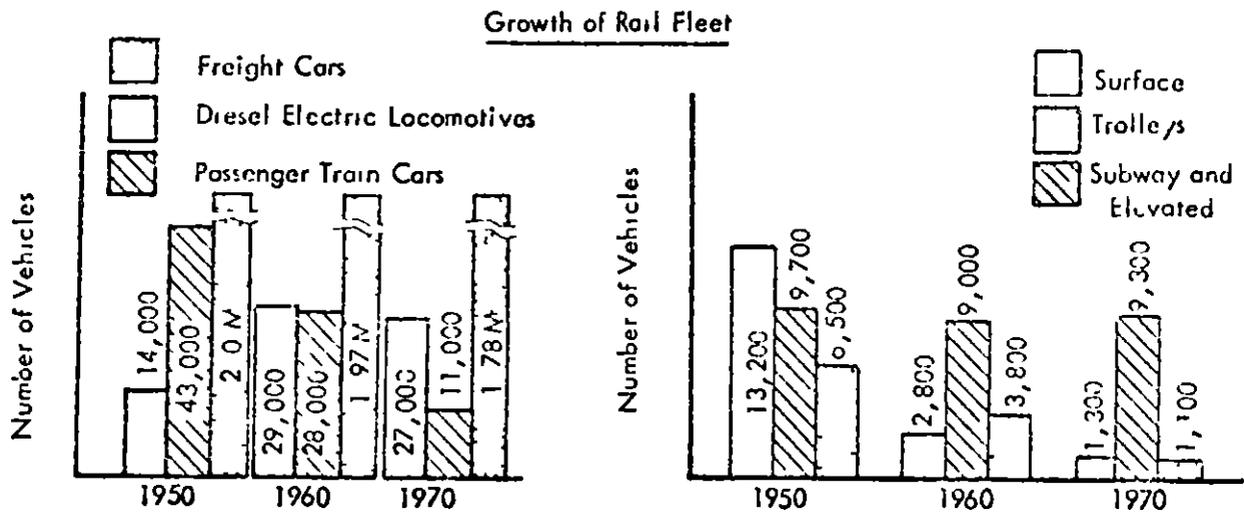- Passenger Cars
- Sports & High Performance
- Economy & Compact
- Imported

- Light Trucks
- Medium
- Heavy Duty

- Street Sweepers
- Garbage Compactors
- Tree Chippers

- Highway
- City
- School

Numbers in Operation

| 87,000,000 | 19,000,000 | Estimated 75,000 | 400,000 |
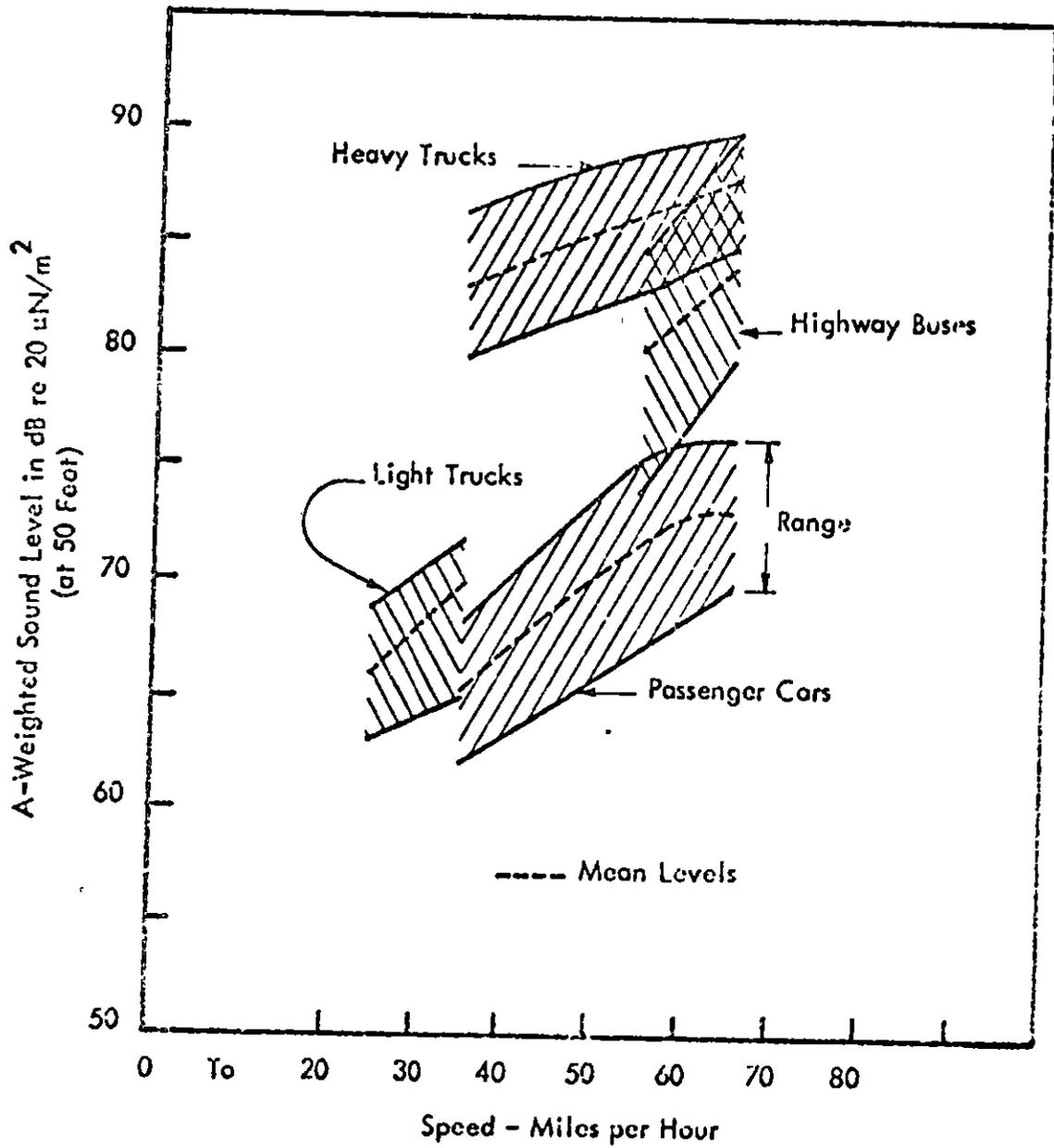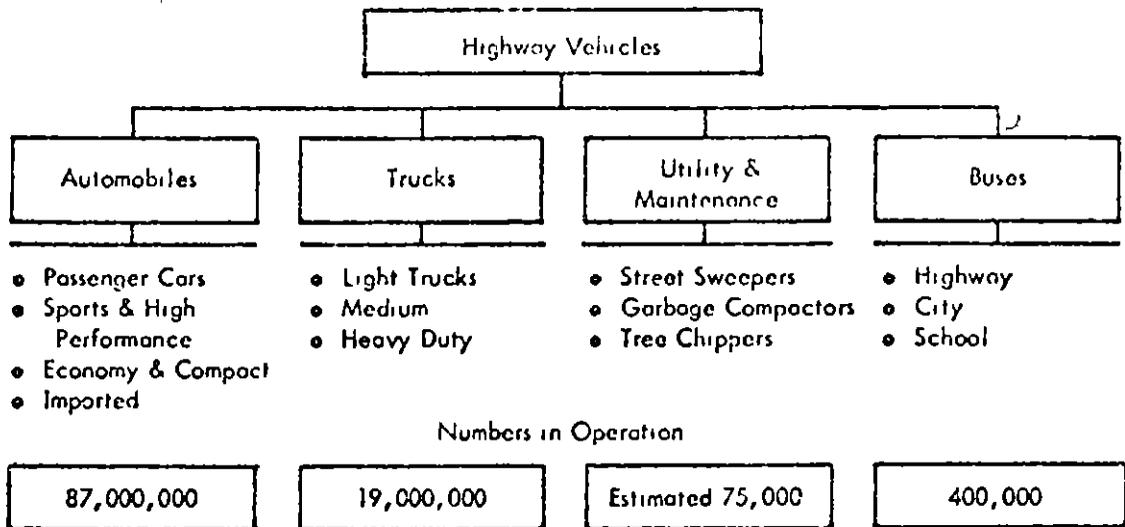
Growth of Number of Highway Vehicles

Autos

Number of Vehicles (in millions)

40 4   61 7   87

1950—60 —70

Trucks

8 6   11.9   19

1950–60–70

Buses

Number of Vehicles (in thousands)

500   400   300   200   100   0

224   272   400

1950 –60 –70

Noise Level – dB(A)

100   90   80   70   60

Passenger 76   Sports 87   Compact 80   Imported 80   70 70 70   74

Interior 90   64

50 ft.

Light 70   Medium 85   Heavy 95   89   80 85

Interior 100   70

50 ft

Compactors 95   Sweeper 90   Chipper 98   76   82   86

Interior 100   80

50 ft.

Highway 87   City 85   School 85   70

Interior 88   70

50 ft

Figure 2: Characteristics of Highway Vehicles

-16-

Commercial Aircraft

2-3 Engine Turbofan	4 Engine Turbofan	4 Engine Widebody Turbofan	3 Engine Wide Body Turbofan	Propeller Aircraft
o Short to Medium Range o B727, B737 o DC-9, BAC-111	o Medium to Long Range o B707, B720 o DC-8	o Long Range o B747	o Medium Range o DC-10, L-1011	o Short Range o F 27 o CV340 440 o DC-3

Average Passenger Capacity

100	150	365	250	40

Typical Range - Miles

250-1500	1000-4000	2000-6000	1000-2500	50-250

Growth of Aircraft Fleet

Typical Noise Levels

Approach and Takeoff Noise Levels Measured at 1000 feet

Figure 3: Characterisitcs of Commerical Aircraft

```
                        V/STOL Aviation

    ┌──────────────┐  ┌──────────────┐  ┌──────────────┐  ┌ ─ ─ ─ ─ ─ ─ ┐
    │ Light Utility│  │ Medium Weight│  │Heavy Transport│  │    STOL     │
    │  Helicopters │  │  Helicopters │  │  Helicopters │  │   Aircraft  │
    │  (2-7 Seats) │  │ (10-15 Seats)│  │ (20-40 Seats)│  │(40-150 Seats)│
    └──────────────┘  └──────────────┘  └──────────────┘  └ ─ ─ ─ ─ ─ ─ ┘
```

- Air-Taxi
- Law Enforcement
- Executive Travel
- Rescue/Ambulance
- Agriculture
- Traffic Monitor
- Scenic/Survey

- Commercial Charter
- Company Transport
- Executive Travel
- Fire Control
- Coast Guard

- Scheduled Transport
- Industrial Cargo
- Construction Lift
- Coast Guard

- Commercial Transport

Number in Service

2900	320	40	? In Planning Stage

Typical Noise Levels

Growth of Helicopter Fleet

Figure 4:   Characteristics of V/STOL Aircraft

Figure 5: Characteristics of General Aviation Aircraft

Figure 6: Characteristics of Rail Systems

Figure 7: Characteristics of Recreation Vehicles

Internal Combustion Engines

Generators
- Battery Chargers
- Air Conditioners
- Auxiliary Power

Lawn Care
- Mowers
- Edgers
- Tillers
- Leaf Blowers
- Snow Blowers

Other Types
- Chain Saws
- Model Aircraft

Number in Service

| 550,000 | 30,100,000 | 2,500,000 |

Typical Noise Levels

Figure 8: Characteristics of Devices Powered by Internal Combustion Engines

TABLE 6. Range of Industrial Machinery, Equipment, and Process Noise Levels*

		Noise Levels – dBA								
		80	85	90	95	100	105	110	115	1?0
1	Pneumatic Power Tools (grinders, chippers etc)			●━━━━━━━━━━━━━━━●						
2	Molding Machines (I S , blow molding, etc)					●━●				
3	Air Blown-Down Devices (painting, cleaning, etc)			●━━━━● ●━●						
4	Blowers (forced, induced, fan, etc)	●━━━━━━●								
5	Air Compressors (reciprocating, centrifugal)				●━━━●					
6	Metal Forming (punch, shearing, etc)		●━━━━━●							
7	Combustion (furnaces, flare stacks)	●━━━━● (measured 25 ft from source)								
8	Turbo-generators (steam)	●(measured 10 ft. from source)								
9	Pumps (water, hydraulic, etc.)	●━━━●								
10	Industrial Trucks (LP gas)			●						
11	Transformers		●							

*Measured at operator positions, except for 7 and 8.

-23-

TABLE 7   Range of Building Equipment Noise Levels to Which People Are Exposed

A-WEIGHTED NOISE LEVEL

LAMP BALLASTS AND VAPOR
DIFFUSERS
MIXING BOXES
FAN COIL
TRANSFORMERS
PUMPS
BOILERS
STEAM VALVES
CHILLERS
ELEVATORS
AIR COMPRESSORS
COOLING TOWERS
FANS
DIESEL EMERGENCY GENERATOR

W — INTERVENING WALL
D — DUCT TREATMENT
E — ENCLOSURE OF EQUIP
R — INTERVENING ROOF STRUCTURE
S — BUFFER ZONE FLOOR BETWEEN SOURCE AND OCCUPANT S FLOOR
V — VIBRATION ISOLATION OF EQUIPMENT

● NOISE LEVEL AT 3 FT FROM SOURCE
○ NOISE LEVEL AT OCCUPANT'S POSITION

-24-

TABLE 8: Noise Levels of Home Appliances and Building Equipment
Adjusted for Location of Exposure (IN dBA)

Noise Source	Level of Operator Exposure*	Level of Exposure** of People in Other Rooms
Group I Quiet Major Equipment and Appliances		
Refrigerator	40	32
Freezer	41	33
Electric Heater	44	37
Humidifier	50	43
Floor Fan	51	14
Dehumidifier	52	15
Window Fan	54	47
Clothes Dryer	55	48
Air Conditioner	55	48
Group II Quiet Equipment and Small Appliances		
Hair Clipper	60	40
Clothes Washer	60	52
Stove Hood Exhaust Fan	61	53
Electric Toothbrush	62	42
Water Closet	62	54
Dishwasher	64	56
Electric Can Opener	64	56
Food Mixer	65	57
Hair Dryer	66	51
Faucet	66	51
Vacuum Cleaner	67	60
Electric Knife	68	60
Group III Noisy Small Appliances		
Electric Knife Sharpener	70	62
Sewing Machine	70	62
Oral Lavage	72	62
Food Blender	73	65
Electric Shaver	75	53
Electric Lawn Mower	76	55
Food Disposal (Grinder)	76	68
Group IV Noisy Electric Tools		
Electric Edger and Trimmer	81	61
Hedge Clippers	84	64
Home Shop Tools	85	75

*Termed "primary exposure"
**Termed "secondary exposure"

IV. Existing Noise Levels (Step 2)

    A. Some Typical Outdoor Values

        1. The outdoor daytime residual noise level in a wilderness, such as the Grand Canyon rim, is of the order of 16 dB(A), on the farm it is of the order of 30 to 35 dB(A), and in the city it is of the order of 60 to 75 dB(A). (8)

        2. Noise levels for the urban population are shown in Table 9. (6)

            L_{dn} = day-night noise level

        3. Outdoor day-night sound levels are shown in Figure 9 for various locations. (6) Figure 10 shows the national population as a function of exterior day-night sound levels. (6)

    B. Some Typical Indoor Values --- see Table 10. (6)

V. Effects of Noise (Basis for Step 3)

    A. General Comments (3)

Information on effects of noise is best for hearing loss due to noise at work. Other effects of occupational noise, except speech intelligibility interferences, are less certain. These are changes in psychological and physiological states, including annoyance and sleep interruptions. The last two are principal complaints against community and aircraft noise. Property damage by actual vibrational or boom destruction and by depreciation because noise paths and patterns impinge on the property is known, and is to some degree measurable and predictable. Effects on animals seem to have been studied very little. These effects are of concern for wildlife around airports and along highways, and for fish and wildlife in

-26-

TABLE 9   Estimated Percentage of Urban Population (134 Million) Residing
In Areas With Various Day-Night Noise Levels Together With
Customary Qualitative Description Of The Area

Description	Typical Range L_{dn} in dB	Average L_{dn} in dB	Estimated Percentage of Urban Population	Average Census Tract Population Density, Number of People Per Square Mile
Quiet Suburban Residential	48-52	50	12	630
Normal Suburban Residential	53-57	55	21	2,000
Urban Residential	58-62	60	28	6,300
Noisy Urban Residential	63-67	65	19	20,000
Very Noisy Urban Residential	68-72	70	7	63,000

32
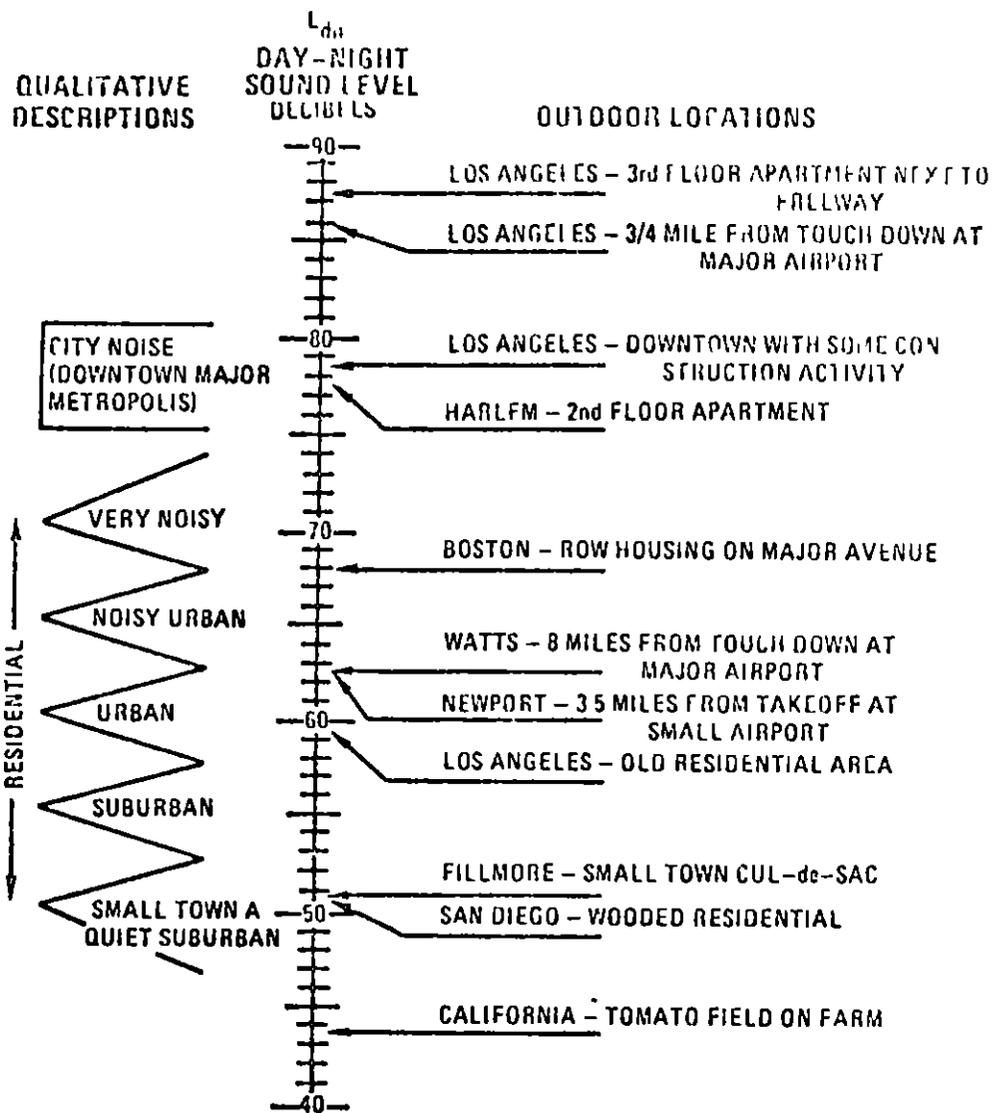
Figure 9: Outdoor Day-Night Sound Level in dB (re 20 micropascals) at Various Locations[4]
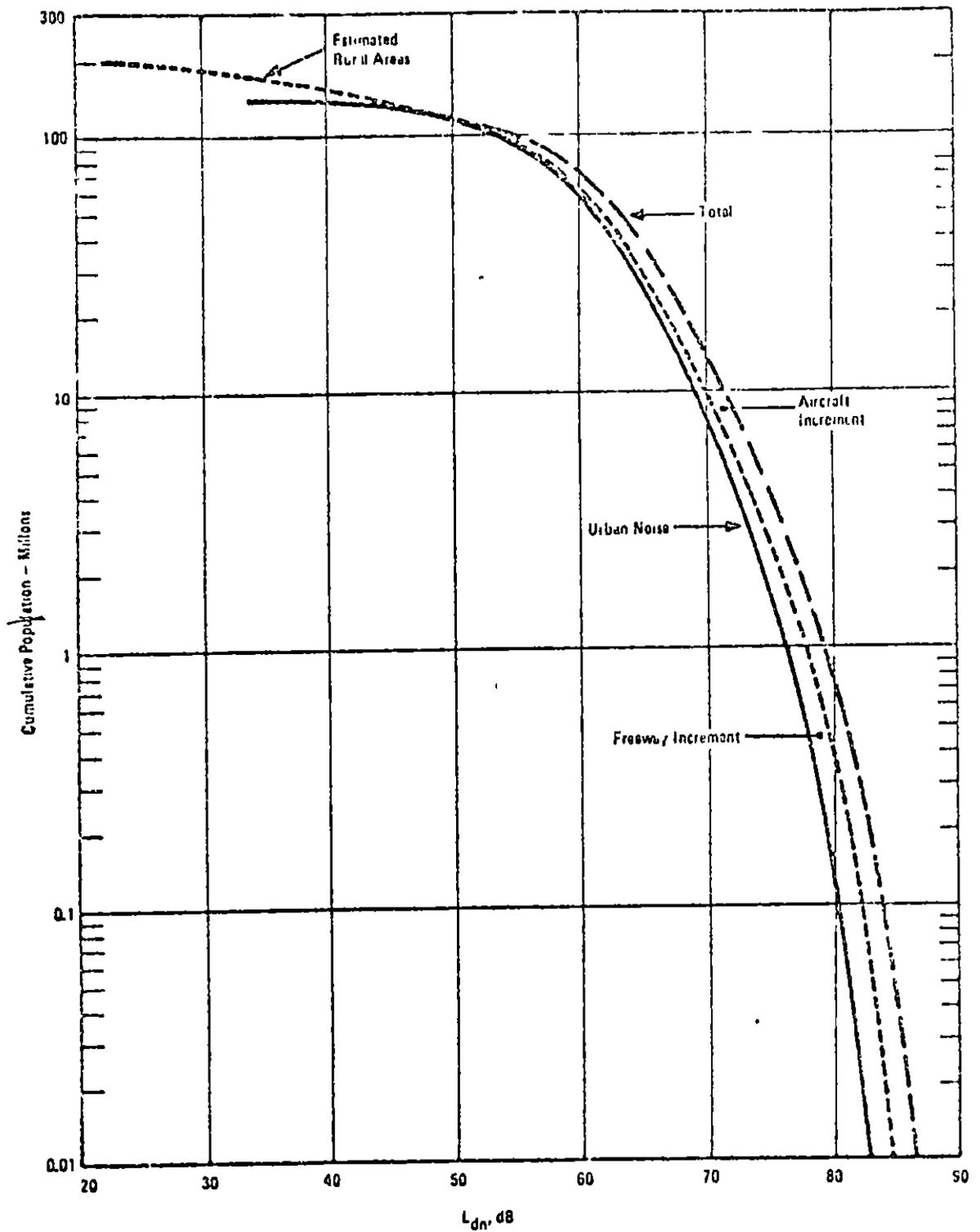
Figure 10.   Residential Noise Environment of the National Population As a Function
of Exterior Day-Night Average Sound Level[B-5]

TABLE 10. Equivalent Sound Levels in Decibels Normally Occurring Inside Various Places [6]

SPACE	L_{eq}(+)
Small Store (1-5 clerks)	60
Large Store (more than 5 clerks)	65
Small Office (1-2 desks)	58
Medium Office (3-10 desks)	63
Large Office (more than 10 desks)	61
Miscellaneous Business	63
Residences	
Typical movement of people - no TV or radio	40-45
Speech at 10 feet, normal voice	55
TV listening at 10 feet, no other activity	55-60
Stereo music	50-70

(+) These measurements were taken over durations typical of the operation of these facilities

-30-

the pathways of sonic boom. In the first instances habitats may be lost, but the creatures have a chance to migrate and to reestablish beyond the reach of the noise. If there are bad immediate effects on those in the sonic boom paths, there is no escape time

B. Principles of Hearing (2)

    1. Figure 11 shows the functional diagram of the human ear.

    2. Sound is generated by a source producing vibrations (sound waves) that may travel through any media and which, in air, actuate the hearing mechanisms of humans and animals. These vibrations set in motion the ear drum and small bones or ossicles of the middle ear as shown in the schematic drawing in Figure 11. The motion of the ossicles, in turn, produces vibrations in the fluid in the inner ear's sensory organ, the cochlea. The vibrations are then transduced into nerve impulses by sensory hair cells and transmitted to the brain, where they are perceived as sound or, depending upon circum- stances, as noise.

C. Hearing Changes and Losses

    1. There are two types of hearing changes caused by noise exposure Temporary threshold shift (TTS) is the lessened ability to hear weak auditory signals, from which there is recovery in a matter of hours and at most in 2 to 4 weeks Noise-induced permanent threshold shift (NIPTS) is a loss from which there is no re- covery. The relations between the two are not clear.
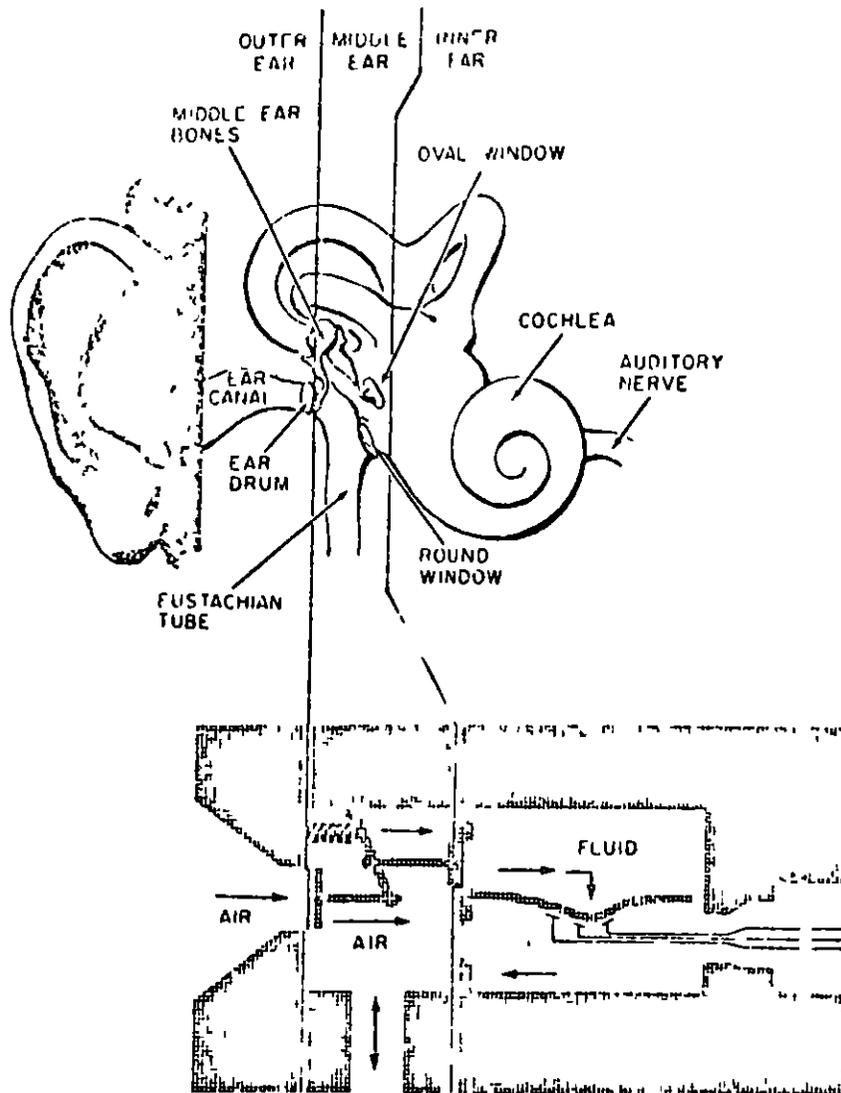
Figure 11. Functional Diagram of Ear

2. For both conditions higher SPLs for long time periods increase severity. By its nature TTS has been easier to study. Some things are known about TTS is that it increases linearly with the average noise level, from about 80 dB up to 130 dB. It is proportional to the fraction of time that the noise is present; therefore steady noise is the major offender.

3. From extended observations several things can be said about NIPTS, a form of deafness.

   (a) Exposures of 8 h/day for several years, to SPLs above 105 dBA are sure to produce NIPTS in a normal unprotected ear. The A in dBA refers to the A scale of measurement, with this scale approximating the frequency response of the human ear

   (b) The first and most severe NIPTS is at frequencies in the neighborhood of 4,000 Hertz (Hz). Hertz is the unit describing frequencies in cycles per second. The ear transmits sound to the brain best at frequencies between 1,000 and 4,000 Hz

   (c) If there is going to be partial recovery of the loss, that is, if part of the loss is TTS, almost all such recovery will occur in 2 weeks. There will be some added recovery in a month. Single event injury, as a gun shot near the ear, may show recovery up to 2 months

   (d) Noise-induced permanent threshold shift is not progressive after the person is moved from the noise. Neither is a

-33-

noise-damaged ear more susceptible to further injury than a normal ear

(e) Regular exposure to moderate noise does not make the ear more resistant to occasional exposures to high-intensity noise. The ear does not toughen.

(f) Susceptible individuals cannot be identified before they suffer hearing losses. Monitoring audiometry detects early NIPTS before it becomes severe.

(g) After onset, further NIPTS cannot be avoided except by reducing the noise exposure. There is no way to restore loss from NIPTS.

(h) In the occupational setting, NIPTS will appear in almost all men exposed 8 h/day to broadband noise above 105 dBA It will appear in about 50 percent of those exposed similarly to a level of 95 dBA. It will not appear in anyone at a level below 80 dBA.

D. Interference with Speech Communication

1. Interference with speech communication by noise impedes our activities and understanding of one another at work, in the home, and in the general social scene.

2. With the increase of the speed and power of machines in manufacture, construction, office work, on the highways, and in the home, the interference noise has become all pervasive.

3. See Figure 12 for visual portrayal of speech interference.
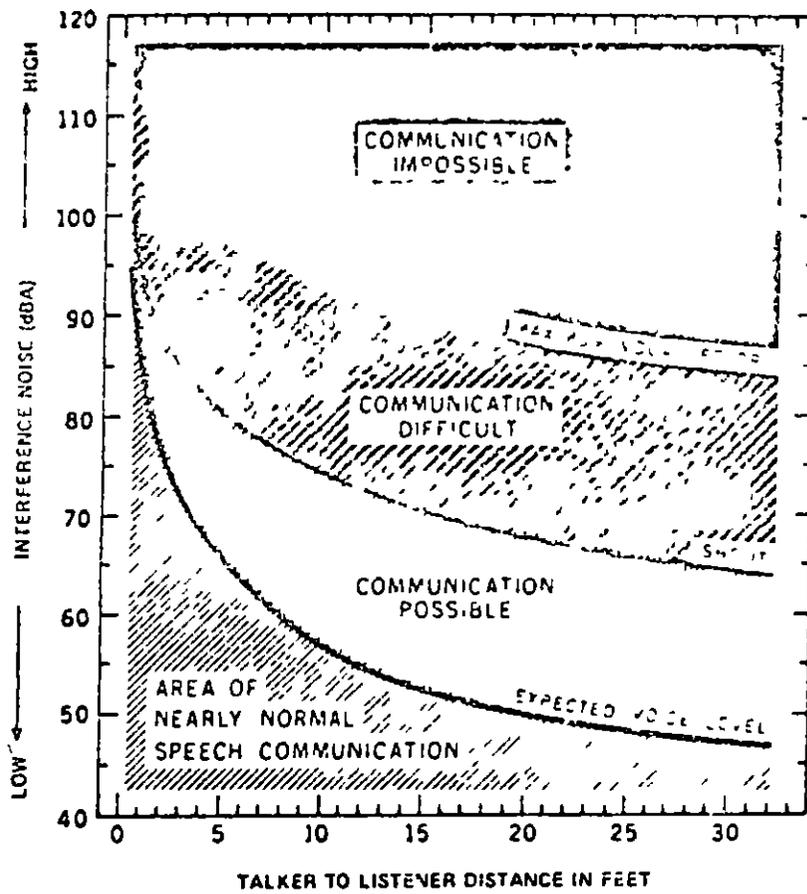
Figure 12. Speech Interference Levels

E. Annoyance

    1. To venture into the annoyance effects of noise is to encounter the subjective response of people to noise head-on

    2. Figure 13 shows typical community responses to noise levels (1).

F. Other Effects

    1. Disruption of sleep and rest.

    2. Reduction in work performance.

VI. Noise Standards and Criteria (Step 3)

A. Terminology

    1. A statistical analysis of the noise level gives the percentage or total time that the value of the noise level is found between any two set limits. Such data can be presented directly in the form of histograms, or be used to obtain a cumulative distribution in terms of the "level exceeded for a stated percentage of time". For the sample statistical distribution of Table 11, the noise level exceeds 60 dB(A) for 1 percent of the hour, 55 dB(A) for 10 percent of the hour, 50 dB(A) for 50 percent of the hour, and 45 dB(A) for 90 percent of the hour These noise levels are abbreviated symbolically as L_1, L_{10}, L_{50} and L_{90}, respectively. (8)

    2. Definitions (1)

Community Noise Equivalent Level - Community Noise Equivalent Level (CNEL) is a scale which takes account of all the A-weighted acoustic energy received at a point, from all noise events causing

-36-
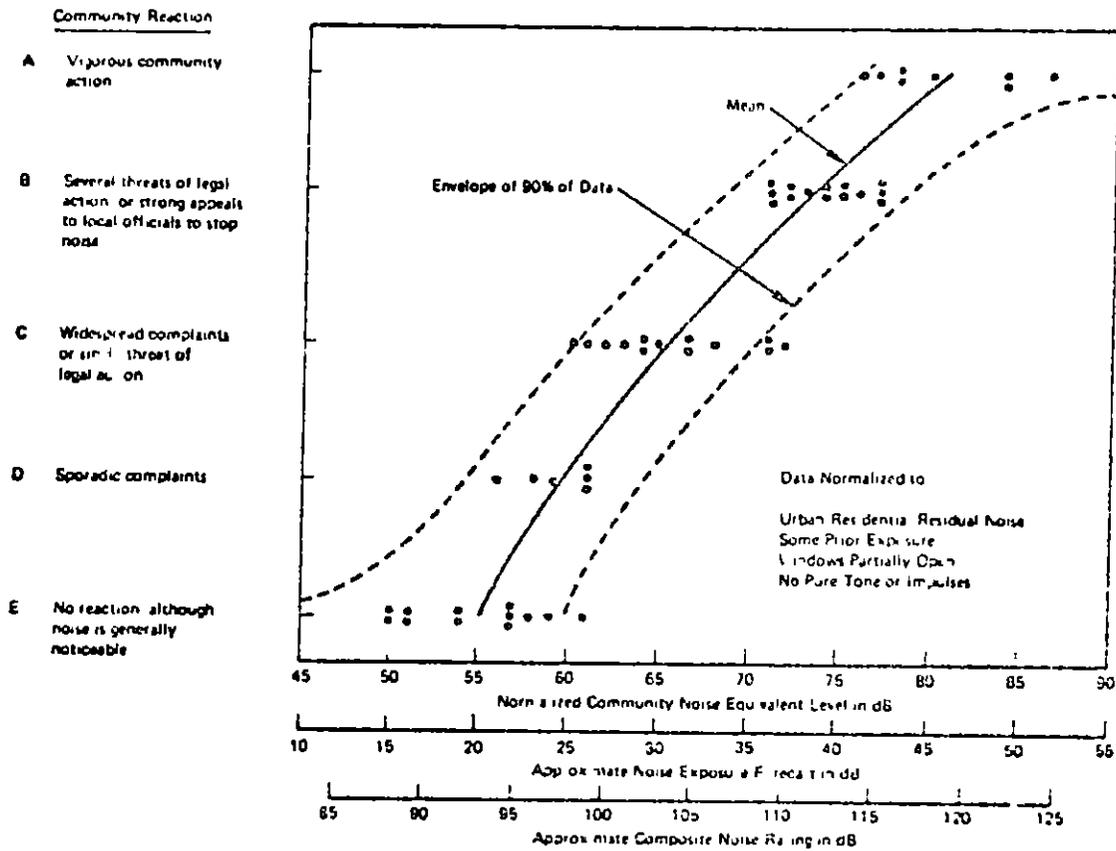
Figure 13.   Community Reaction to Intrusive Noises of Many Types as a
Function of the Normalized Community Noise Equivalent Level

TABLE 11. Example of Statistical Distribution of Outdoor Noise analyzed in Intervals of 5 dB Widths

Interval in dB(A)	Percent of Total Time	Cumulative Percent of Total Time
61 through 65	1	1
56 through 60	9	10
51 through 55	40	50
46 through 50	40	90
41 through 45	10	100

noise levels above some prescribed value   Weighting

factors are included which place greater importance upon

noise events occurring during the evening hours (7 00 p.m.

to 10 00 p.m.) and even greater importance upon noise

events at night (10.00 p.m. to 6 00 a m)

Composite Noise Rating - Composite noise rating (CNR) is

a scale which takes account of the totality of all aircraft

operations at an airport in quanitifying the total aircraft

noise environment. It was the earliest method for evaluating

compatible land use around airports and is still in wide use

by the Department of Defense in predicting noise environments

around military airfields. Basically, to calculate a CNR value

one begins with a measure of the maximum noise magnitude from

each aircraft flyby and adds weighting factors which sum the

cumulative effect of all flights. The scale used to describe

individual noise events is perceived noise level (in PNdB),

the term accounting for number of flights is $10 \log_{10} N$ (where

N is the number of flight operations), and each night operation

counts as much as 10 daytime operations Very approximately,

the noise exposure level at a point expressed in the CNR scale

will be numerically 35-37 dB higher than if expressed in the

CNEL scale.

Effective Perceived Noise Level (EPNL) - A physical measure

designed to estimate the effective "noisiness" of a single

noise event, usually an aircraft fly-over, it is derived from

instantaneous Perceived Noise Level (PNL) values by applying

322

corrections for pure tones and for the duration of the noise.

Noise Exposure Forecast - Noise exposure forecast (NEF) is a scale (analogous to CNEL and CNR) which has been used by the federal government in land use planning guides for use in connection with airports.

In the NEF scale, the basic measure of magnitude for individual noise events is the effective perceived noise level (EPNL), in units of EPNdB. This magnitude measure includes the effect of duration per event. The terms accounting for number of flights and for weighting by time period are the same as in the CNR scale. Very approximately, the noise exposure level at a point expressed in the NEF scale will be numerically about 33 dB lower than if expressed in the CNEL scale.

Noise and Number Index (NNI) - A measure based on Perceived Noise Level, and with weighting factors added to account for the number of noise events, and used (in some European countries) for rating the noise environment near airports

Noise Pollution Level (L_{NP} or NPL) - A measure of the total community noise, postulated to be applicable to both traffic noise and aircraft noise. It is computed from the "energy average" of the noise level and the standard deviation of the time-varying noise level.

NOYS - A unit used in the calculation of perceived noise level.

Perceived Noise Level (PNL) - A quantity expressed in decibels that provides a subjective assessment of the perceived "noisiness" of aircraft noise. The units of Perceived Noise Level are Perceived Noise Decibels, PNdB

Speech-Interference Level (SIL) - A calculated quantity providing
a guide to the interfering effect of a noise on reception of
speech communication. The speech-interference level is the arith
metic average of the octave-band sound-pressure levels of the
interfering noise in the most important part of the speech
frequency range. The levels in the three octave-frequency
bands centered at 500, 1000, and 2000 Hz are commonly averaged
to determine the speech-interence level Numerically, the
magnitudes of aircraft sounds in the Speech-Interference Level
scale are approxima ly 18 to 22 dB less than the same sounds
in the Perceived Noise Level Scale in PNdB, depending on the
spectrum of the sound.

3. See Table 12 for a general comparison of CNR, NEF, and CNEL.

B. Criteria for Protection of Public Health and Welfare (6)

1. The phrase "health and welfare" is defined as complete physical,
    mental and social well-being and not merely the absence of
    disease and infirmity

2. See Table 13 for criteria

C. Design Objectives --- see Table 14.

D. Example Standards for Federal Highway Administration (9)

1. Table 15 portrays the design noise/land use relationships.

2. The exterior noise levels apply to outdoor areas which have
    regular human use and in which a lowered noise level would be
    of benefit. These design noise level values are to be applied

TABLE 12 , Factors Considered in Each of Three Methods Used for Describing the Intrusion of Aircraft Noise into the Community

Factor	Composite Noise Rating (CNR)	Noise Exposure Forecast (NEF)	Community Noise Equivalent Level (CNEL)
Basic measure of single event noise magnitude	Maximum perceived noise level	Tone-corrected perceived noise level	A-weighted noise level
Measure of duration of individual single event	None	Energy integration	Energy integra on
Time periods during day	Daytime (7 AM-10 PM) Nighttime (10 PM-7 AM)		Daytime (7 AM-7 P M) Evening (7 PM-10 PM) Nighttime (10 PM-7 AM)
Approximate weighting added to noise of single event which occurs in indicated period	Daytime 0 dB Nighttime 12 dB		Daytime 0 dB Evening 5 dB Nighttime 10 dB
Number (N) of identical events in time period	10 log N		10 log N
Summation of contributions	Logarithmic		Logarithmic

TABLE 13. Yearly Average* Equivalent Sound Levels Identified as Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety

		Indoor		To Protect Against Both Effects (b)	Outdoor		To Protect Against Both Effects (a)
	Measure	Activity Interference	Hearing Loss Consideration		Activity Interference	Hearing Loss Consideration	
Residential with Outside Space and Farm Residences	L_{dn}	45		45	55		55
	$L_{eq}(24)$		70			70	
Residential with No Outside Space	L_{dn}	45		45			
	$L_{eq}(24)$		70				
Commercial	$L_{eq}(24)$	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	$L_{eq}(24)$	(a)	70	(a)			
Industrial	$L_{eq}(24)(d)$	(a)	70	70(c)	(a)	70	70(c)
Hospitals	L_{dn}	45		45	55		55
	$L_{eq}(24)$		70			70	
Educational	$L_{eq}(24)$	45		45	55		55
	$L_{eq}(24)(d)$		70			70	
Recreational Areas	$L_{eq}(24)$	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	$L_{eq}(24)$				(a)	70	70(c)

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a   Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity.

b   Based on lowest level.

c   Based only on hearing loss.

d   An $L_{eq}(8)$ of 75 dB may be identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24 hour average, i.e., no greater than an L_{eq} of 60 dB.

Note   Explanation of identified level for hearing loss. The exposure period which results in hearing loss at the identified level is a period of 40 years.

*Refers to energy rather than arithmetic averages

-43-

334

TABLE 14   Design Objectives for Indoor A-Weighted Sound Levels in Rooms with Various Uses

Type or use of space	Approximate A weighted sound level (dBA)
Concert halls, opera houses, recital halls	21 to 30
Large auditoriums, large drama theaters, churches (for excellent listening conditions)	Not above 30
Broadcast, television and recording studios	Not above 34
Small auditoriums, small theaters, small churches, music rehearsal rooms, large meeting and conference rooms (for good listening)	Not above 42
Bedrooms, sleeping quarters hospitals residences, apartments, hotels, motels (for sleeping, resting relaxing)	34 to 47
Private or semiprivate offices, small conference rooms, classrooms, libraries, etc (for good listening conditions)	38 to 47
Living rooms and similar spaces in dwellings (for conversing or listening to radio and television)	38 to 47
Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc (moderately good listening)	42 to 52
Lobbies laboratory work spaces drafting and engineering rooms, general secretarial areas (for fair listening conditions)	47 to 56
Light maintenance shops office and computer equipment rooms, kitchens, laundries (moderately fair listening conditions)	52 to 61
Shops, garages, power-plant control rooms, etc (for just-acceptable speech and telephone communication)	56 to 66

*As recommended by an acoustical engineering firm on the basis of experience with acceptability limits exhibited by the users of the rooms [16]

TABLE 15   Design Noise Level/Land Use Relationships

Land Use Category	Design Noise Level - L_{10}		Description of Land Use Category
A	60dBA (Exterior)		Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet
B	70 dBA (Exterior)		Residences, motels, hotels public meeting rooms schools churches, libraries, hospitals picnic areas recreation areas, playgrounds, active sports areas and parks
C	75 dBA (Exterior)		Developed lands, properties or activities not included in categories A and B above.
D	--		For requirements on undeveloped lands see paragraphs 5a(5) and (6), this PPM.
E	55 dBA (Interior)		Residences, motels, hotels, public meeting rooms schools, churches, libraries, hospitals and auditoriums

-45-

at those points within the sphere of human activity (at approximate ear level height) where outdoor activities actually occur. The values do not apply to an entire tract upon which the activity is based, but only to that portion in which the activity occurs. The noise level values need not be applied to areas having limited human use or where lowered noise levels would produce little benefit. Such areas would include but not be limited to junkyards, industrial areas, railroad yards, parking lots, and storage yards.

3. The interior design noise level in Category E applies to indoor activities for those situations where no exterior noise sensitive land use or activity is identified. The interior design noise level in Category E may also be considered as a basis for noise abatement measures in special situations when, in the judgment of FHWA, such consideration is in the best public interest. In the absence of noise insulating values for specific structures, interior noise level predictions may be estimated from the predicted outdoor noise level by using the following noise reduction factors

Building Type	Window Condition	Noise Reduction Due to Exterior of the structure	Corresponding Highest Exterior Noise Level Which Would Achieve an Interior Design Noise Level of 55 dBA
All	Open	10 dB	65 dBA
Light Frame	Ordinary Sash Closed	20	75
	With Storm Windows	25	80
Masonry	Single Glazed	25	80
Masonry	Double Glazed	35	90

Noise reduction factors higher than those shown above may be used when field measurements of the structure in question indicate that a higher value is justified. In determining whether to use open or closed windows, the choice should be governed by the normal condition of the windows. That is, any building having year round air treatment should be treated as the closed window case. Buildings not having air conditioning in warm and hot climates and which have open windows a substantial amount of time should be treated as the open window case.

E. Example Standards for HUD (10) --- see Table 16.

VII. Prediction of Noise Levles

A. General Model (10)

1. Sound travels through the air in waves, with characteristics of frequency (cycles per second or Hertz) and wave length.

2. If a sound were created at a point, a system of spherical waves would propagate from that point outward through the air at a speed of 1100 feet per second, with the first wave making an ever-increasing sphere with time. As the wave spreads, the height of the wave or the intensity of the sound at any given point must diminish as the fixed amount or energy is spread over an increasing surface area of the sphere This phenomenon is known as geometric attenuation of the sound.

3. For point-source propagation

sound level$_1$ - sound level$_2$ = 20 log $\dfrac{r_2}{r_1}$

where the sound level at station one minus the sound level at station two is equal to twenty times the log of the ratio

-47-

TABLE 16: Residential Noise Level Guidelines

(Note: Measurements and projections of noise exposures
         are made at appropriate heights above site
         boundaries)

GENERAL EXTERNAL EXPOSURES - dB(A)	AIRPORT ENVIRONS - NEF ZONE
UNACCEPTABLE	
Exceeds 80 dB(A) 60 minutes per 24 hours Exceeds 75 dB(A) 8 hours per 24 hours (Exceptions are strongly discouraged and require a 102(2)C environmental statement and the Secretary's approval)	greater than 40
DISCRETIONARY-NORMALLY UNACCEPTABLE	
Exceeds 65 dB(A) 8 hours per 24 hours Loud repetitive sounds on site (Approvals require noise attenuation measures, the Regional Administrator's concurrence and a 102(2)C environmental statement)	between 30 and 40
DISCRETIONARY-NORMALLY ACCEPTABLE	
Does not exceed 65 dB(A) more than 8 hours per 24 hours	less than 30
ACCEPTABLE	
Does not exceed 45 dB(A) more than 30 minutes per 24 hours	less than 30

oi the radii. This means that for every doubling of distance, the sound level will decrease by 6 decibels. In other words, if station one were at a distance of 50 feet from the point source and, if station two were a distance of 100 feet from the point source, the sound level measured at point two would be 6 dB less than the sound level measured at point one. This is called the inverse-square law. This kind of relationship holds true for single vehicles and aircraft when sound is propagating in free air, either from the airplane to the ground in a complete spherical sense, or in the case of an automobile on the ground when the propagation field is only half a sphere. See Figure 14.

4. Line-source propagation --- When a number of vehicles are lined up and constitue a continuous stream of noise sources, the situation is no longer characterized by a spherical or hemis- pherical spreading of the sound, but rather the reinforcement by the line of point-sources makes the propagation field like a cylinder or half a cylinder. In this case the equation is as follows:

For Line-Source Propagation.

$$\text{sound level}_1 - \text{sound level}_2 = 10 \log \frac{r_2}{r_1}$$

Thus, the decrease in sound for each doubling of distance from a line source is only 3 decibels. When we consider noise levels from busy highways, we will essentially consider the noise source of the highway as an infinite line source and a 3 dB per
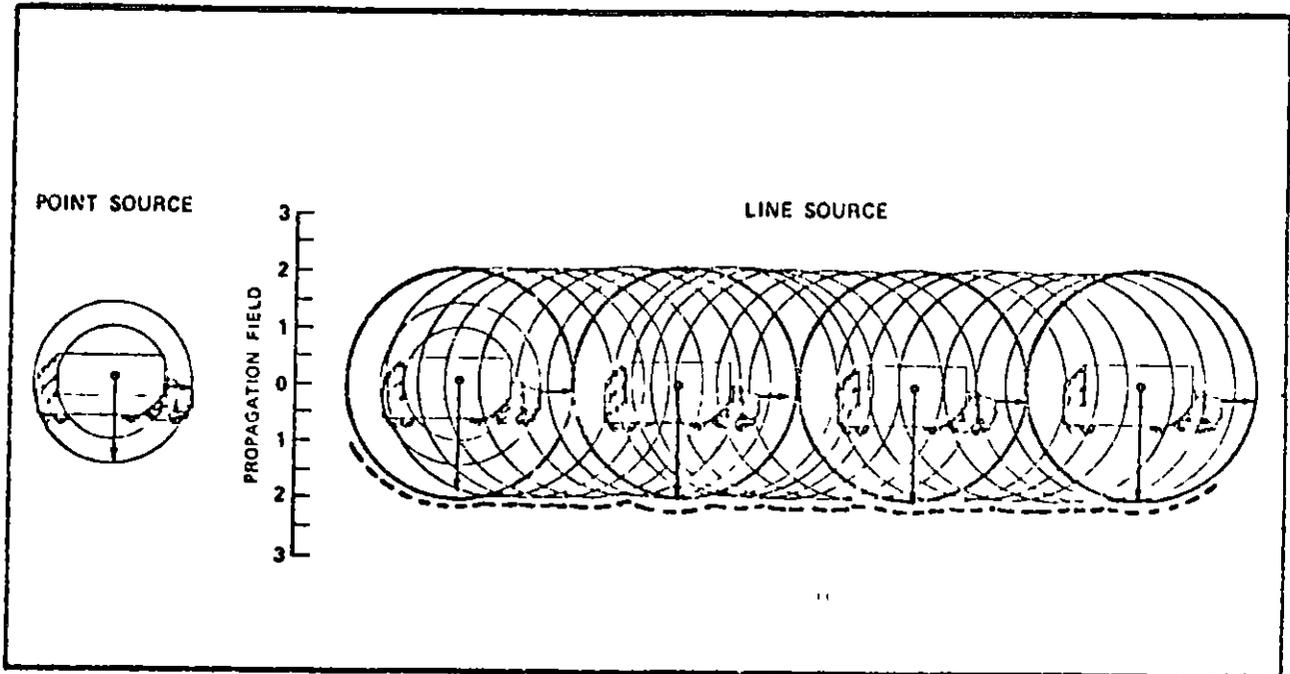
327

Figure 14. Sound Propagation Comparison

doubling of distance propagation rate will be utilizea. However, when we consider a situation such as the propagation of noise from a multi-car transit train, the 3 dB per doubling of distance propagation rate will be applicable to approximately a distance of 3/10 of the length of the train or a finite line source. Beyond that distance, a 6 dB per doubling of distance attenuation rate should be applied.

B. Aircraft Noise Exposure Contour Model (11)

1   This model is based on the physical characteristics of the runways and flights using the facility

2. The program provides the user with three output options. The first is the Contour Output, which provides a list of coordinates that give the location of a specified Noise Exposure Level. Also given is the area enclosed by these points. The second output, the Grid Output, provides the Noise Exposure Level for each set of coordinates specified by the user. Finally, the Diagnostic Output provides a subtotal, the Effective Perceived Noise Level, which includes the present flight condidered plus all previous flights. This output also gives a complete description of the present flight being considered, including such other information as aircraft type, percent thrust, and elevation.

3. The outline of the model, including input requirements, output options, and flexibility, is shown in Table 17.

TABLE 17. Aircraft Noise Exposure Contour Model Outline

A. Input Requirements of Model

1. Number of runways, and for each runway:

   (a) Runway coordinates - Cartesian coordinates of runway end points,

   (b) Distance from the end of runway to the start of takeoff roll;

   (c) Distance from the end of runway to the touchdown point, and

   (d) Number of flights on each runway (a flight is a given aircraft type on a given flight path), and for each flight.

   (1) Type of flight - takeoff or landing,

   (2) Type of aircraft,

   (3) Number of operations, and

   (4) Number of segments composing each operation, and for each segment.

   a) Segment length,

   b) Flight path climb angle,

   c) Thrust level of aircraft, and

   d) Radius of curved segment.

B. Output Options of Model

1. Contour Output

   (a) Required inputs:

   (1) Noise exposure (NE) level;

   (2) Tolerance of NE Level, and

   (3) Estimate of X and Y coordinates of location of first point with given NE level.

   (b) Output:

   (1) X and Y coordinates of locations of specified NE level, and

   (2) Area enclosed by points on line connecting the prescribed NE level.

-52-

2   Grid output
    (a) Required inputs.
         (1) X and Y coordinates of the starting point on grid,
         (2) Increments for X and Y, and
         (3) Number of points on X and Y axis.
    (b) Output.
         (1) NL levels for each set of coordinates specified.
3. Diagnostic output
    (a) Required inputs:
         Sames as one required for grid output.
    (b) Output:
         (1) Flight number,
         (2) Aircraft type,
         (3) Slant range to observer,
         (4) Elevation angle to observer,
         (5) Percent thrust;
         (6) EPNL (Effective Perceived Noise Level of aircraft
              at slant range H),
         (7) Corrections for
              a) Shielding;
              b) Excess ground attenuation, and
              c) Number of operations.
         (8) Net EPNL, and
         (9) Subtotal EPNL - includes present flight plus all
              preceding ones.

C. Flexibility of Model
    1. Has been converted for use on the IBM 360/195.   (The original
        program was written for the CDC 6400.)
    2. Program has been designed to generate NL levels, but it can
        easily be modified to produce
        (a) EPNL.

             $NL = EPNL + 10 \log NOPS - 88$
             $(NOPS = \text{number of observations})$

        (b) NEF

             $NOPS = NOPS_{day} + 16.67 \, NOPS_{night}$

                              -53-

3   Program presently has.

   (a) 24 noise curves - IPNL vs Slant Height - one curve for takeoff
        and one for landing for each of 12 aircraft types.

   (b) 6 thrust correction curves - IPNL vs Percent Thrust, and

   (c) 2 excess ground attenuation curves - IPNL vs Distance.

4. Finally, new relationships developed for both new and existing
    aircraft may be easily incorporated into the program as data
    statements.

C. Highway Noise Prediction Models

1. The Federal Highway Administration PPM 90-2 (9) stated that two
    highway noise prediction methods were acceptable:

    (a) The method in the National Cooperative Highway Research
         Program Report 117 (12).

    (b) The method in the Department of Transportation, Transportation
         Systems Center Report DOT-TSC-FHWA-72-1. (13)

2   A model developed at Argonne National Laboratory was published
    in 1973 (11). Basically, the model requires characteristics of
    the highway segments as input. The characteristics include a
    description of the traffic using the highway (the speeds and volumes
    of both automobiles and trucks), the physical dimensions of the
    facility (the elevation, depression, grades and surface types),
    and the aspects of the environment bordering the facility
    that have an effect on the noise levels (the landscaping, structures,
    and barriers). Fundamentally, the model calculates a noise level
    at a particular point along the highway and a perpendicular
    distance away from the highway. Once this noise level is
    calculated, the model moves outward an incremental distance
    away from the facility and calculates another noise level. This
    process is repeated until the model reaches a maximum pre-
    scribed distance away from the highway. At this point, the model
    moves farther down the highway and calculates another group of
    noise levels. This is repeated until the model has covered the
    entire length of the highway. The model prints out a contour
    map of noise levels at given distances from the facility over

3 4 5

the entire length of the facility.

(a) Figure 15 shows a schematic diagram for the *use* of the model. The fiftieth percentile noise level is that noise level that will be exceeded 50% of the time.

(b) Two options for estimating highway noise are available to the user of this model. The first allows the user to predict noise levels at various desired heights above ground level. This may be of special importance in an area that is composed of multi-story apartments and commerical sturctures. The second option allows the user to calculate the predicted noise levels in the fiftieth or tenth percentile noise levels. The tenth percentile noise level is that level that will be exceeded 10% of the time. The fiftieth percentile level is useful as it provides what may be termed the median noise level. On the other hand, the tenth percentile noise level will also be required as many noise standards are beginning to incorporate this level.

VIII. Noise Control Principles (Basis for Step 5)

   A. Reduction of Vibrating Sources (3)

   Noise is produced by an aerodynamic disturbance such as air moving in a duct, discharging from a pneumatic tool,and being pushed about along the surfaces of speeding cars and trucks, beat about by propellors, or squeezed and thermally expanded through jet engines Or noise is generated by the vibration of structures purposefully set in motion, as in internal-combustion engine or the shuttle of a
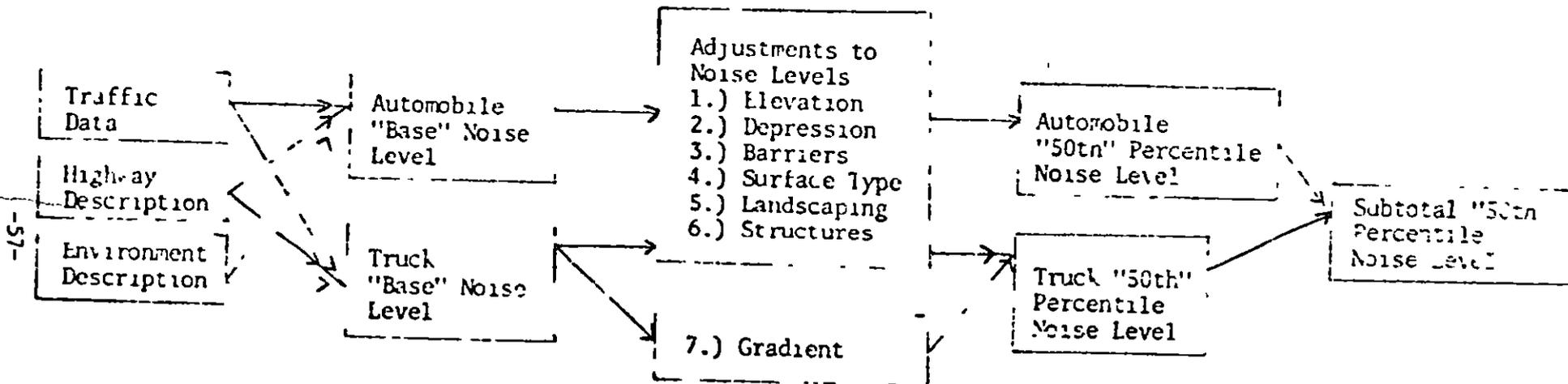
Figure 15. Determination of noise levels

loom. Noise is also produced by a surface that is vibrating as it is
connected to the moving parts of machinery, such as a fan housing or
a mounting of a punch press or a packaging machine   Control at the
source then depends on altering the aerodynamic characteristics of
the vibrating air by dimensional changes, by smoothing its flow to
reduce turbulence, and by absorbent materials along its path

B.   Enclosure of the Source (3)

The escape of noise can be prevented by complete enclosure of the noise-
maker. With provision for heat dissipation, motors and production
machines can be put on vibration mounts and housed in sound-absorbent
materials. Escape can be somewhat reduced by partial enclosure.
Abosorbent baffles at air inlets and outlets can reduce the escape
of fan noise. Mufflers control the escape of exhaust air and gas
noise partly by altering the aerodynamics and partly by absorbing
existing vibrations.

C.   Attenuation by Absorption(3)

The behavior of noise which has already been generated and which has
escaped into a room can be modified. Acoustic characteristics which
influence the behavior of emitted noise in a room are the absorption
coefficients of surfaces exposed to the noise; the reverberation time
which depends on the noise source and the room, and the transmission
losses through the walls, floor, and ceiling. Acoustically,
reverberation time of a room is the period required for any
sound to decrease by 60 dB after the source is cut off and absorption
takes place. This technique of control depends on reducing the noise

level by improving the absorption characteristics of the room.
Modification and wall and ceiling qualities is the principle procedure,
and floors as well where change does not interfer with floor service-
ability Application of this approach is a demanding task for a skilled,
experienced acoustic control expert.

IX. Noise Control Practices (Step 5)

A. Industrial Noise (3)

The methods of noise control in the United States are well formulated
for controlling industrial noise. The principles embrace plant
planning, substitution of quieter equipment, processes, and materials,
reduction at the source and reduction by transmission by air.

B. Subsonic Aircraft Noise Abatement (10)

The following lists some of the current noise abatement techniques,
procedures, and other alternatives to counter subsonic aircraft noise
sources

1. Aircraft Design or Modification

New quiet engine designs with high bypass ratios and low velocity
nets.

Acoustically treated nacelles and ducts

Exhaust silencers for reciprocating and turboshaft engines

Noise suppression for on-board auxiliary power units

Rotor and propeller aerodynamics for reduced noise

Noise suppression for mechanical components such as helicopter
gear boxes

Vehicle aerodynamics to allow for steeper ascent and descent,
and/or reduction in time required for ascent/descent

3̷

2. Aircraft Operations

   Restrict operations by type of aircraft, number of operations or

   time of day

   Power cutback on takeoff or steep climb-out depending on situation

   Steep or multi-segment approach depending on situation

   Preferential runway assignments

3. Aircraft Mainenance

   Restrict engine "runups" during ground maintenance operations

   Maintenance of additonal hardware for noise suppression (i.e.,

   treated nacelles or auxiliary-power-unit silencers

4. Aircraft Route Location

   Avoid noise sensitive areas in new route assignments

   Modify existing routes to avoid noise sensitive areas

   Utilize noise-insensitive areas for ascent and descent paths

5. Landscape Architecture

   Shield airport surroundings from noise resulting from aircraft

   ground operations and surface vehicle operations

6. Acoustic Insulation

   Insulation of dwellings against aircraft noise

   Insulation of commercial structures against aircraft noise

7. Land Use

   Control by zoning authorities for compatible land use

C. Highway Noise Abatement (10)

   1. Three options for noise reduction are:

      (a) Man-constructed barriers to obstruct or dissipate sound

          emissions

(b) Elevated or depressed highway through grading

(c) Absorption effects of landscapting (trees, bushes, shrubs, etc.)

2. Constructing Barriers.

   A rigid (fairly massive) barrier can be an effective means to reduce noise from highways depending upon the relative heights of the barrier, the noise source, and the affected area, as well as the horizontal distance between the source and the barrier and between the barrier and the noise-affected area.

3. Elevated or Depressed Highways.

   Often a highway in an urban area can be built above or below the surrounding property. Such differences in grade provide some shielding of traffic noise and can reduce the noise levels at adjacent properties.

4. Effects of Planting.

   Planting adjacent to a highway produces little physical reduction in noise level unless it is very dense and of significant depth.

5. Some other noise control measures for highways.

   (a Limitations on allowable grades.

   (b) Road surface repairs

   (c) Route locations planned to insure maximum separation between roadway and existing noise sensitive areas and to make maximum use of shielding provided by natural barriers

   (d) Provide for compatible use of land adjacent to highways

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