RISK MANAGEMENT IN PUGET SOUND

Joseph T Pizzo
Oceanographic Institute of Washington

RECOGNITION OF THE PROBLEM

The preservation of our environment has been the object of increasing concern by industry, the public, and the government. The possibility of oil and other hazardous materials spills during transport, transfer, and production operations clearly represents a potential danger to the natural resources in Puget Sound. The ecological impacts, however, represent only a part of the total impact. Although the public has become increasingly aware of ecological considerations, there is an intense interest in the positive and negative impacts to the human population and properties.

The risk of an undesirable event is continually growing, due to the increased activity to fulfill societal needs and demands. The problem is further compounded by a consideration of the socio-economic requirements, the legal implications and the political involvement of society. The potential adverse impacts on both social and natural systems and how they can be mitigated offers one of the most demanding challenges to decision makers in our industrial, scientific, and political sectors.

These potentially increasing dangers to persons, property and the environment require prompt and effective actions placing more emphasis on prevention rather than on clean-up, restoration and litigation. To justify the risk to society by pollution it is generally stated that the need for the product by society outweighs the risks involved to the population at large or to the immediate environment. It is probably assumed that there is enough resilience in the ecosystems to restabilize or refurbish any imbalances that occur. In any case, we must realize that there is a cost tradeoff that must be balanced against the benefits that society gains from the enterprise. The question to ask society is what level of risk is it willing to accept, along with its consequential results, to obtain the necessities and some amenities of daily living.

ACCEPTABLE LEVEL OF RISK

What is an acceptable level of risk? There are many agencies that are continuall promoting safety programs to reduce accidents, yet people are still willing to take chances as accident statistics show (Table 1). Methodologies for computing acceptable risk levels, based on historical accident records have been developed (Ref. 1 and 2). One of the implications of these studies is that people generall will accept a level of risk for voluntary activities (skiing, flying, smoking, driving a car) which is higher, 10^{-4}, than the level of natural mortality, 10^{-6}. For involuntary activities (such as work-related risk or natural disasters), they demand a much lower level, around 10^{-7} or 10^{-8} (Figure 1). A factor not discussed, however, is the difference in involuntary nature of risk for a person who may choose to avoid living in an area which is susceptible to earthquake, floods, or hurricanes; as opposed to the person who considers himself relatively free from "involuntary risk" yet may be exposed to a massive release of hazardous material.

These studies point out that there is a greater public tolerance of minor disasters, such as automobile accidents or individual drownings, than of accidents involving the simultaneous loss of many lives, as in the TITANIC or major airline disasters. Although a risk analyst may be able to "prove" that this type of emotional reaction is not rational, the emotion-factor does exist and influences public acceptance of how regulatory agencies do their jobs. The magnitude of this factor was made readily apparent in 1969 and 1970 when the Army shipped obsolete poison gas stockpiles through cities to a disposal point. The ecological equivalent was demonstrated in the TORREY CANYON, the METULA, and possibly in the ARGO MERCHANT.

Determination of acceptable risk levels may require sampling of opinion from any public and private sectors, to obtain a consensus for development of criteria for the decision making process. Acceptable risk levels must be treated as relative values and approximations. These evaluations can give the decision maker the ability to evaluate change and provide a basis for comparison of magnitude involved. Using these approaches we may be able to establish an acceptable risk level for oil spillage and have some way of making comparisons of estimating the costs to the individual and to the community.

RISK ELEMENTS AND LOSS FACTORS

Consideration of the losses from an undesired event must include: risks to the community at large (i.e., the human population at risk, the properties at risk, the systems at risk, and the environment at risk).

Tanker Traffic and Accidents

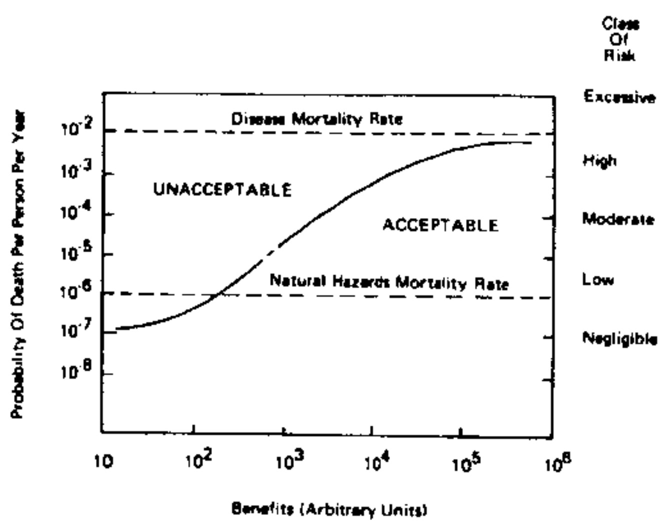
In 1974, 516 oil tankers (both crude and product) entered the Puget Sound region Most of these went to Seattle, Anacortes, and Cherry Point-Ferndale. There were slightly more than 3,000 inbound non-self propelled oil tank vessels (barges); one-third of these went to Seattle.

On the average during 1974, about 50,000 barrels of crude and 150,000 barrels of refined products were being transferred on Puget Sound waters every day. This

Table 1 SOME U.S. ACCIDENT DEATH STATISTICS (Ref. 1) 1967, 1968

Accident	Total Deaths		Probability of Death per Person per Year	
	1967	1968	1967	1968
Motor Vehicle	53,100	55,200	2.7×10^{-4}	2.8×10^{-4}
Falls	19,800	19,900	1.0×10^{-4}	1.0×10^{-4}
Fires, burns	7,700	7,500	3.9×10^{-5}	3.8×10^{-5}
Drowning	6,800	7,400	3.4×10^{-5}	3.7×10^{-5}
Firearms	2,800	2,600	1.4×10^{-5}	1.3×10^{-5}
Poisoning	2,400	2,400	1.2×10^{-5}	1.2×10^{-5}
Cataclysm	155	129	8×10^{-7}	6×10^{-7}
Lightning	110	162	6×10^{-7}	8×10^{-7}

Figure 1 A Benefit-Risk Pattern (Ref. 1)



means that about 45 tankers, averaging from 15,000-30,000 deadweight tons (dwt), used Puget Sound ports each month. By comparision during 1976, about 213,000 barrels of crude and 174,000 barrels of refined products were being transferred on Puget Sound waters every day. The substantial increase in marine transportation of crude is due to the curtailment of Canadian crude via pipeline. This has resulted in an increase of crude tanker traffic to the refineries, which will increase even more after the Canadian supply is cut off entirely on April 1, 1977 (Ref. 3 and 4).

APPLICATION OF RISK METHODOLOGIES

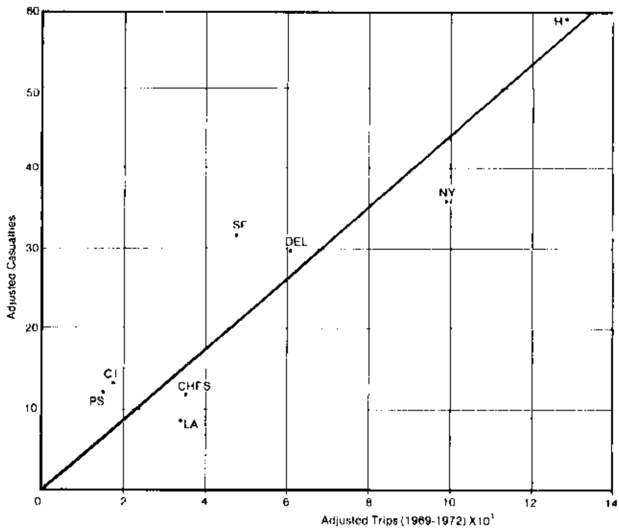
Risk methodologies have been applied successfully in the past several decades to complex systems problems in the aerospace, chemical, and nuclear industries. In the past 5 years these same methodologies have been transferred to the marine industry. OIW demonstrated this in their 1972 report Risk Analysis of the Oil Transportation System (Ref. 5). In this report a risk analysis, which is basic for the Risk Assessment Management Program (RAMP) outlined in this paper, was developed for Washington State. OIW's 1975 report Offshore Petroleum Transfer Systems for Washington State (Ref. 6) provided risk assessment forecasts of tanker casualties and spillage. A strong correlation between the number of casualties and the number of vessel trips for 7 major U.S. ports (including Puget Sound) was developed (Figure 2) and utilized in forecasting potential number of tanker accidents in Washington waters to the year 2000. A 1976 report by the Federal Energy Administration states that a similar correlation has been obtained between the number of spills and the number of tanker trips. Used properly, the results of this type of risk assessment would provide important information on potential accidents and spillage. To accomplish this decision makers need additional information on the probable impacts of such spillage, on people, property and the environment. From this data preventive actions can be taken. A total systems approach is therefore considered necessary to review adequately the hazards of navigational activities to society. The Risk Assessment Management Program is an approach to this problem.

THE RISK ASSESSMENT MANAGEMENT PROGRAM (RAMP) AN APPROACH

This paper outlines a Risk Assessment Management Program (RAMP) involving mitigating measures and control actions to reduce the risk of hazardous material pollution in Washington State. The risk methodologies are applicable to all hazardous materials. Since the current national headlines, public concern, and discussions have centered around oil pollution, we will illustrate RAMP in terms of the hazards associated with oil spills from tankers. RAMP includes interdisciplinary studies of probabilistic risk analyses, the behavior of spilled oil on water and land, resources-at-risk, socio-economic effects, and cost/benefit analyses of development options, and mitigating measures and control actions.

The objective of undertaking RAMP is to aid in the decision process by effectively reviewing the benefits of expanded petroleum activities in contrast with the costs of controlling and/or correcting hazardous operations that may have detrimental impacts on the environment. The results of this cost/benefit analysis should be meaningful to decision makers. The basic format for RAMP is outlined in Figure 3.

Figure 2



(PS = Puget Sound, Strait of Juan de Fuca, Wash. coast; CI = Cook Inlet; LA = Los Angeles, Long Beach, San Diego; CHES = Chesapeake Bay; SF = San Francisco & Bay; DEL = Delaware Bay; NY = New York, New Haven, Bridgeport, Port Jefferson; H = Gulf Coast, including Houston)

Step 1. Scenario Development

The scenarios that follow assume a level of continuity and stability.

In Washington State, the geographical focus of petroleum activities has been in Greater Puget Sound and the Strait of Juan de Fuca. (Potential activities on t outer continental shelf off the coast of Washington (Ref. 4), and those on the Columbia River and possibly British Columbia waters do add another dimension to the problem.) Limiting our projections to Greater Puget Sound and the Strait o Juan de Fuca we have the following basic scenarios:

- Traditional market only--refineries in Western Washington serve Washingto Oregon and Idaho with product.
- Transshipment to other markets--facilities in Western Washington serve additional markets beyond the traditional market area with crude and/or product.
- Independent deepwater berths--terminals at each of the refineries, independently owned and operated, handling crude and product.
- Common-use crude oil terminal--a single crude oil terminal in Washington, used by all crude oil tankers utilizing Washington waters to supply refineries, whether in or out of state.

These scenarios reflect the broad development issues now before the public. Th state has struggled with these variations for many years without establishing a oil transportation policy. The situation is so fluid that the ultimate outcome is quite uncertain.

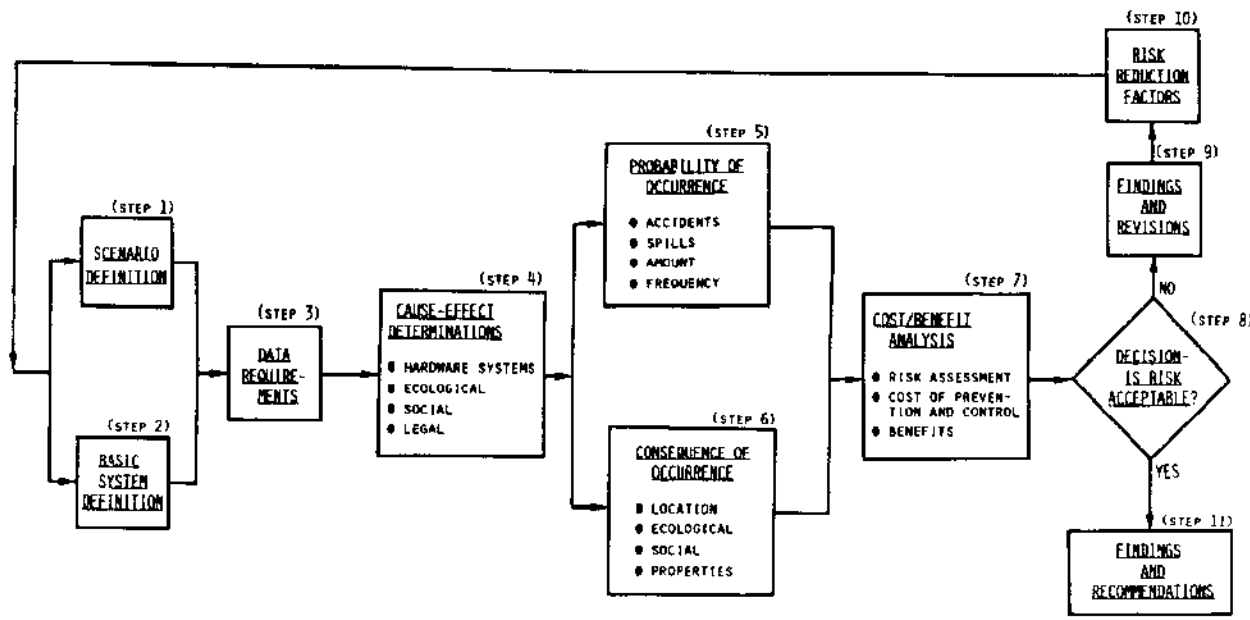
Variations of each of these basic elements as well as combinations of them are reasonable. In a dynamic, iterative program such as RAMP, other scenarios can be developed and investigated in terms of their consequential effects.

Step 2. Basic System Definitions

This step defines the system to be analyzed during transport, transfer and production phases of operations. There are numerous subsystems to be considered i the transfer and production phases are included. Restricting the system to the transport phase, however, reduces considerably the number of subsystems to be considered. Typical subsystems are:

- Tankers
- Barges
- Onshore Pipeline
- Submarine Pipelines
- Vessel Traffic System

Figure 3 - Risk Assessment Management Program (RAMP)



Step 3. Data Requirements

The logical analysis of any system requires an unbiased data base. Difficulties arise in determining the validity, the availability, and the adequacy of the data base. The data base for this program would contain:

- System elements
- Environmental Factors
- Socio-economic Factors
- Pathways and Traffic
- Safety Requirements
- Cost Factors
- Federal and State Regulations
- Historical Casualty and Pollution Incident Data
- Inherent Nature of Hazardous Material

Step 4. Cause/Effect Determination

There are several mechanisms for establishing the relationships between system elements, cause/effect relationships, environmental impacts, and preventative or corrective measures.

For example in a Gross Hazards Analysis (GHA) format, failure rates of structural elements could be considered in the context of the age of vessels, hours of operation, etc. The objective of this approach is to systematically scrutinize operations involving hazardous materials while minimizing the budgetary factors of time and cost.

The format of a Cause/Effect Step Matrix approach can be used to identify such relationships as:

- Facility Component Usage Affecting Activities--Causal Factors
- Activities--Causal Factors Affecting Potential Environmental Changes
- Potential Environmental Changes Affecting Threatened Environmental Resources
- Threatened Environmental Resources and Mitigating Measures and Cost Factors

Network construction depends on dividing the problem in relatable units, that is, causes, conditions, effects, mitigating measures and cost factors. A stepped matrix enables a continous portrayal of the use-to-cause-to-condition relationship. The linear attachment of condition to consequent condition to effect to mitigating measures to costs permits the development of a multiple response network. The framework should be an information source for a comparative evaluation of both qualitative and quantitative impacts and costs.

Other techniques that are applicable are Failure Mode and Effect Analysis and Fault Tree Analysis.

Step 5. Probability of Occurrence

The primary objective of this step is to determine the frequency and severity ‹ potential polluting incidents. Similar analyses can be constructed for oil transfer and production operations, submarine pipelines, lightering operations shipment by tank barge, and related industrial developments such as refineries and tank farms. For purposes of illustration, casualties and spills associate‹ with transport operations will be considered.

Utilizing historical data on the number of casualties and the mean number of casualties per unit of exposure, the probability of the number of casualties c‹ be described as a negative binomial density function. This is based on the statistical theory of accidents, and assumes that the number of casualties is based on a Poisson process and that the unit of exposure is itself a random variable with a gamma distribution. This model, in the context of accident theory, is called the hypothesis of accident proneness.

It was shown in the OPTS study that the number of casualties is directly proportional to the number of vessel trips. Thus, it is possible to accurately forecast the number of casualties by considering the number of contemplated vessel trips as the exposure variable. The forecasts will vary from port to port because of variations in traffic density, port geometry, types of vessel traffic systems, environmental factors, etc.

The number of casualties leading to spills then can be calculated from histori‹ data. Further, the percent occurrence of vessel casualties can be determined ‹ type of casualty (collisions, groundings, rammings, and other), and by region (coastal, entrance, and harbor).

An analysis also can be made of accident reduction factors for different types vessel tracking systems. This includes preventative measures such as bridge-t‹ bridge communications, traffic separation routes, vessel movement reporting systems, and radar.

Step 6. Consequence of Occurrence

Determining the consequential effects on the environment from a pollution inci‹ is challenging. The variety and range of events resulting from a pollution incident present a formidable array of parameters to examine (Table 2). The maj‹ forces that come into play are: the location of the pollution incident; the i‹ herent nature of the hazardous substance; the quantity of material; the dynamic‹ of the environment at the time of the incident; and the success of the clean-u‹ effort.

The potential resources-at-risk include people, property, and the environment ‹ may be affected. To gain a perspective of the possible consequences, Bayesian Analysis could be used to assess the relative impacts of hypothetical pollutio‹ incidents under varying environmental conditions. The Delphi Method is also a useful tool in assessing complex systems. This subjective approach relies on expert opinion and provides an experiential measure of the consequential effec‹ on the environment.

Table 2

Parameter List

- Shoreline Characteristics
  - Type of Shore Environment
    - Rocky
    - Sandy
    - Estuary
  - Size
  - Use (Shoreline & Adjacent Waters)
    - Commercial
    - Industrial
    - Parks & Recreational
    - Residential
    - Special Areas
      - Scientific Research Areas
      - Wildlife Preserves

- Oceanography
  - Flushing Action
  - Wave Height (Hs)
  - Current Patterns
    - Tidal Cycles
    - Subsurface
  - Prevailing Winds
  - Temperature Profile
  - Salinity Density
  - Visibility
  - Navigational Obstructions

- Terrestrial Ecology
  - Species
  - Significant Populations
  - Stability
  - Diversity
  - Food Chain
  - Endangered Species
  - Life-History
    - Habitat Requirements
    - Breeding Patterns
    - Migration Patterns

- Aquatic Ecology
  - Species
    - Mobile
    - Relatively Fixed
  - Significant Populations
    - Commercial
    - Sport
  - Stability
  - Diversity
  - Food Chain
  - Endangered Species
  - Life-History
    - Habitat Requirements
    - Breeding Patterns
    - Migration Patterns

- Material
  - Type
    - Crude (Alaskan Middle East)
    - Product
  - Quantity (gallons)
    - <100
    - <1,000
    - <10,000
    - <100,000
    - <1,000,000
    - >1,000,000
  - Spreading Characteristics
  - Duration/Persistence
    - Evaporation
    - Weathering
  - Toxicity

- Clean-Up Efficiency
  - Oceanographic Conditions
  - Meteorological Conditions
  - Response Time
  - Recovery Ability
  - Cost/Material/Equipment Availability

- Aesthetics
  - Odor
  - Sight

An alternative method of determining ecological impacts is to construct models which can describe environmental changes. This is a very arduous developmental program involving state-of-the-art modeling and extensive baseline data collection (Figure 3).

Step 7. Cost/Benefit Analysis

To facilitate evaluation it is useful to measure the costs and benefits which would result from each decision. A methodology is necessary to estimate costs to affected industries, people and property.

The discharge of a pollutant into the environment can produce extensive economic losses to the public and associated industries. Clean-up operations divert money and manpower resources from other productive activities. Biological effects destroy valuable fish and wildlife resources. Other losses are direct physical property damage and indirect loss of the use of recreational facilities including aesthetic effects. Furthermore, possible litigation costs must be included and the original costs of installation and upkeep of the facility must be considered.

There are numerous parameters that contribute to the actual losses from a pollution incident, including such complex factors as location, weather and time of year. Some of these cost estimates are outlined in Table 3. On the other hand preventative measures as vessel design changes (double hulls), cargo size limitations, compartmentalization, additional navigational and communication equipment may introduce a prohibitive financial cost to industry outweighing the benefits. A set of general criteria that can be applied to the risk assessment process could be developed. These criteria should facilitate the grading of options, strategies, and alternatives and the determination of their viability in a regional or local context. One must be careful not to introduce biases by weighing alternatives that favor one result over another. Questions must be answered such as:

- What is the goal in mind, in terms of facility utilization in the long term and short term time span

- What is a tolerant level of pollution

- What price/task level is the local community willing to accept

The actual costs require sophisticated economic analyses and detailed modeling of the environmental effects to estimate the losses. One method of evaluating alternatives is cost-benefit analysis. The results of this analysis can be expressed as the ratio of the cost of implementing the action to the savings resulting from a particular course of action. If this information is not available, a worst-case analysis can be constructed.

Step 8. Decision for Alternative Action

At this point a decision is needed to determine if it is necessary or desirable to either improve the system or refine the analysis. If the risk assessement is unacceptable, and time and funds are still available, then the decision is obvious. If the risk assessment is acceptable, and time and funds still are available, then a decision must be made as to whether or not a more refined analysis would be

Table 3

COST ANALYSIS

Restoration Costs	Clean-Up Cost Factors	Litigation Costs	Industrial and Recreational Losses	Facility Costs
Beaches (Public and Private) Marinas Vessel(s)/ Commodity Port	• Location Distance from Shore • Oceanographic Conditions Wind/Waves/Current Time of Occurrence • Spreading/Diffusion/ Explosion/Fire Spillage/Leakage • Type of Commodity and Quantity Oil LNG Chemical Quantity Waste Water Disposal • Properties of Commodity Toxicity (Plants/Fish/ Animals/Humans Viscosity Solubility Evaporation/Weathering Explosive/Flammable Persistency Thermal Effects (Nuclear Plants) • Response Time • Available Clean Up Resources (Materials and Persons)	• Fines • Court Fees • Damage/Replacement Costs • Time Loss/Work Recreation Stoppage • Insurance	• Aquaculture • Recreation Fishing Swimming Camping Resorts • Industry Fishing Shellfish Aquaculture	• Primary Facility Materials Required Installation Costs e.g. Breakwater Operation Costs e.g. Downtime Maintenance Costs • Secondary Facilities and Operations Dredging Costs Transport Costs • Types of Facilities Storage Refinery Offshore Drilling Pipeline Pegasification Tankers Monobuoys Fixed Piers

worthwhile. If time and funds have been expended, then the analysis of the system must stop, and the findings and recommendations for further research are summarized. The decision to proceed with a follow-on program is then determined by the funding agency.

Step 9. Findings and Proposed System Revision

This step identifies the findings of a given iteration and, based on the findings, proposes revisions which should, or could, improve the system.

Step 10. Risk Reduction and Control

The Risk Reduction and Control phase constitutes the action phase of the program. During this phase, prevention and control measures are developed to achieve a satisfactory risk assessment. If necessary there will be further iterations of the program to test these alternative measures.

The degree of elimination or control of hazards results from a tradeoff between the application of improvements for removal or control of a hazard and the practicality of assuming the risk. The assumption of risk is, in most cases, a decision that must be made at the top management level, since some risks could be sufficiently large to place many parties in jeopardy. Good management projections concerning hazards and risks must be available for effective reduction of risk.

The decisions to reduce a known risk level may be implemented in many ways, including:

- Improved subsystems; equipment, testing, operations and maintenance;
- Diversion of hazardous materials to other modes or systems;
- Improved emergency response;
- Improved accident/incident and system behavior data acquisition and distribution;
- Improved systems controls, regulations and enforcement actions;
- Selection of alternative location(s) for system and operations (where possible) to minimize environmental risks;
- Reducing personnel work loads (i.e., fatigure, physical/mental strains on certain jobs)

Step 11. Findings and Recommendations

Step 11 would provide:

- An identification of the causes and effects of hazards and hazardous conditions;
- A discussion of prevention and control alternatives;

- A hazard classification to provide a qualitative measure of significance for the potential effect of each identified hazardous condition;

- A logical procedure to assess the risks involved under various conditions. The risk assessment can be made for either the present or future. This provides a formal decision-making tool which takes into account all of the important parameters in the system;

- A cost/benefit assessment comparing the effects of reducing risks with the purpose and utilization of the system.

In summary, a Risk Assessment Management Program can ideally be put into operation whenever a new technology is introduced, extended or modified. RAMP can provide decision makers with sufficient information to explore hypothetical situations, and to adequately assess cost/benefit tradeoff relationships. This information can assist in anticipating and evaluating the impacts of technological developments on all sectors of society.

REFERENCES

1. Reactor Safety Study, WASH-1400, U.S. Nuclear Regulatory Commission, October 1975.

2. Starr, C. 1971. "Benefit-Cost Studies in Socio-Technical Systems" Conference on Hazard Evaluation and Risk Analysis, National Academy of Sciences.

3. Oceanographic Institute of Washington. 1976. Oil in Washington: Applicabilit of Models to Marine Environmental Management Questions and Ecological Impacts. National Oceanic and Atmospheric Administration.

4. Oceanographic Institute of Washington. 1977. Summary and Analysis of Environmental Information of the Oregon and Washington Coastal Zone and Offshore Areas U.S. Bureau of Land Management.

5. Oceanographic Institute of Washington. 1972. Risk Analysis of the Oil Transportation System. Oceanographic Commission of Washington.

6. Oceanographic Institute of Washington. 1975. Offshore Petroleum Transfer Systems for Washington State. Oceanographic Commission of Washington.