Unit 1:
How to express Reliability, Failure and Risks

H.P. Nachtnebel

Dept. of Water-Atmosphere-Environment
Univ. of Natural Resources
and Applied Life Sciences
hans_peter.nachtnebel@boku.ac.at

Objectives of this unit

- Providing the basis for risk definition and identification of the main elements of risk

What is risk ??

- What are the elements of risk ?

Structure

- Some definitions
- What is reliability, what is a failure, what is risk?
- How to describe and how to model risk?

Some definitions

- Hazard with intensity X

Hazard
A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability.

Some definitions

- Hazard with intensity X
- Consequences D (Damages, Fatalities, …may reach the level of a Disaster)

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Disaster

A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

A disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk.

Revised definition

- The damage D depends on the intensity of X
- D(X) can be analysed in more detail:
- exposure of populations and property (who and what)
- and the vulnerability of those exposed e.g., sensitivity to the hazard (how)

Vulnerability
The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

For positive factors, which increase the ability of people to cope with hazards, see definition of capacity.

Some additional definitions

- Capacity

Capacity

A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster.

Capacity may include physical, institutional, social or economic means as well as skilled personal or collective attributes such as leadership and management. Capacity may also be described as capability.

Some additional definitions

- Capacity
- Resilience

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Capacity

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Resilience / resilient

The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Some additional definitions

- Capacity
- Resilience
- Mitigation

Capacity

A combination of all the strengths and resources available within a community, society or organizat

Mitigation

Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards.

Resi

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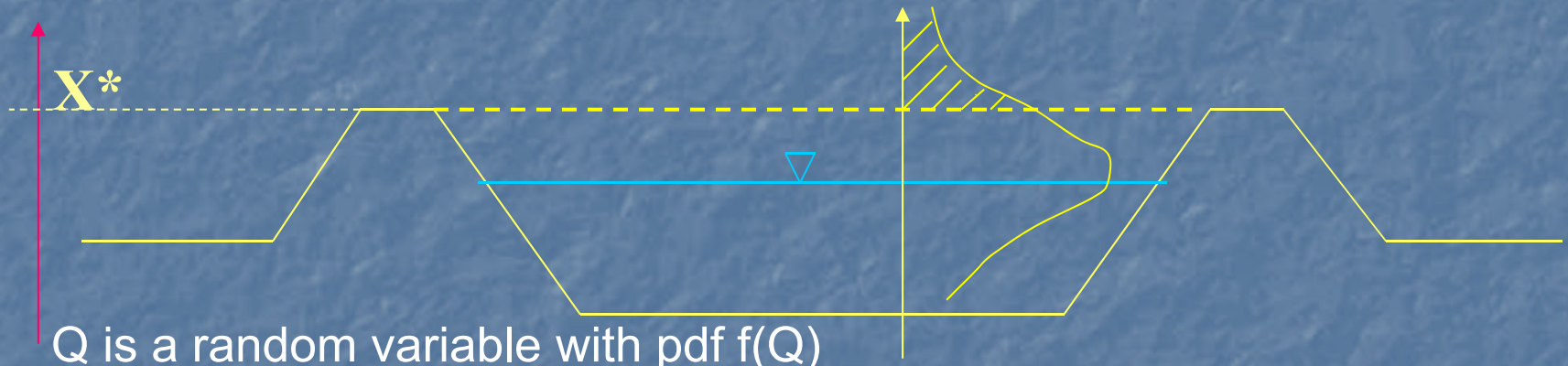
or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Some concepts

Resistance
X

Load Q



Q is a random variable with pdf f(Q)

Reliability: $$Z(X^*) = \int_0^{X^*} f(Q)dQ = \sum_i f(Q_i) \cdot \Delta Q_i$$

Failure rate: V(X*)=1-Z(X*)

What characterises risk ?

An event (hazard)

Its magnitude X

load, dose, demand

Its probability (likelihood) of occurrence f(X)

pdf, likelihood, subjective probability

Its consequences D(X)

what, who is exposed ?

exposure

what are the impacts ?

Loss, response, vulnerability, resistance, capacity, susceptibility

Some definitions: risk analysis

- **Risk Analysis:** The systematic use of available information to characterize risk. (Salter 1997-98)
- **Risk Analysis:** A detailed examination performed to understand the nature of unwanted, negative consequences to human life, health, property, or the environment; (Gratt 1987)
- **Risk analysis** includes both the estimation of a pdf f(Q) and the estimation of respective damages, losses D(Q)

Some definitions: risk assessment

- **Risk Assessment:**". . .emphasizes the estimation and quantification of risk for a region in order to determine acceptable levels of risk and safety;
- to balance the risks of a technology or activity against its social benefits in order to determine its overall social acceptability" (Cutter 1993, 2).
- **Risk Assessment:** Determination of vulnerabilities and hazards in certain location to establish risks and risk probabilities. (D&E Reference Center 1998)

Two examples

- 1. Flood Management

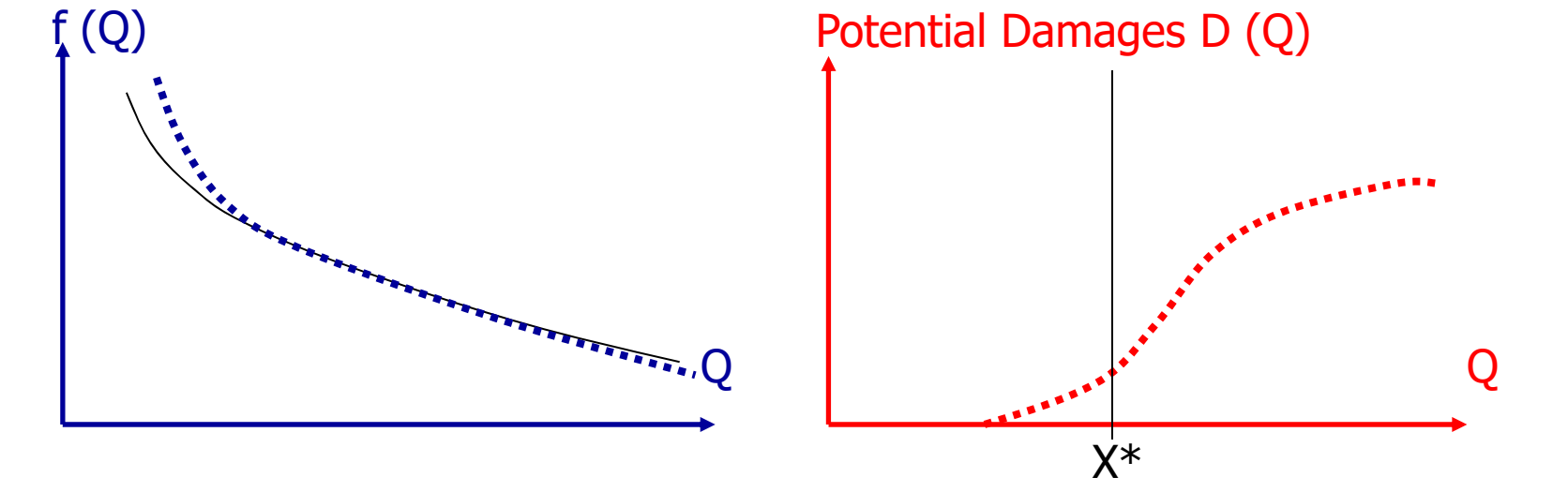
  Engineering Risk

- 2. Groundwater Contamination

  Environmental Health Risk

Risk definition

- A hazardous event
- A probability distribution function (pdf)
- The consequences (damages, victims,..)
- X* is a critical level (existing protective level, buffering capacity,..)



Risk definition

- There is a random event with intensity X (hazard)
- This event has a probability of occurrence f(X)
- This event has consequences (damages) D(X)

- The risk is understood here as

$$R(X^*) = \int_{X^*}^{\infty} f(X) \cdot D(X) \cdot dX = \sum_{X_i > X^*} f(X_i) \cdot D(X_i)$$

$$R(X^*) = \sum_{X_i > X^*} \text{Probability} * \text{Vulnerability} = \text{Probability} * \text{Exposition} * \text{Susceptibility}$$

Expression of risk

- Load — Exposure dose

  Flood discharge — Contaminant concentration

- Resistance — Threshold

  Levee capacity — Threshold concentration

- Failure event - Safety event

  Load/exposure >< Resistance/threshold

Expression of risk

- The expression of risk depends on the way uncertainties in the elements of risk analysis are considered.
- The classical probabilistic formulation generally considers the expected value of risk using the probability density function of exposure/load.

Expression of risk

- In case of engineering risk ER:

$$ER(\rho) = \int_{\rho}^{\infty} L(\lambda) g(\lambda) d\lambda$$

- A typical water resources example consists of calculating the expected economic flood losses above resistance ρ.
- $g(\lambda)$ is probability of an event of magnitude λ
- $L(\lambda)$ is loss function
- ρ is a critical level

Expression of risk

- Similarly, in health risk analysis the so-called **individual (health) risk,** *HR* can be expressed again as an expected value, here expected probability.

$$HR(\rho) = \int_{\rho}^{\infty} DR(\lambda) g(\lambda) \mathrm{d}\lambda$$

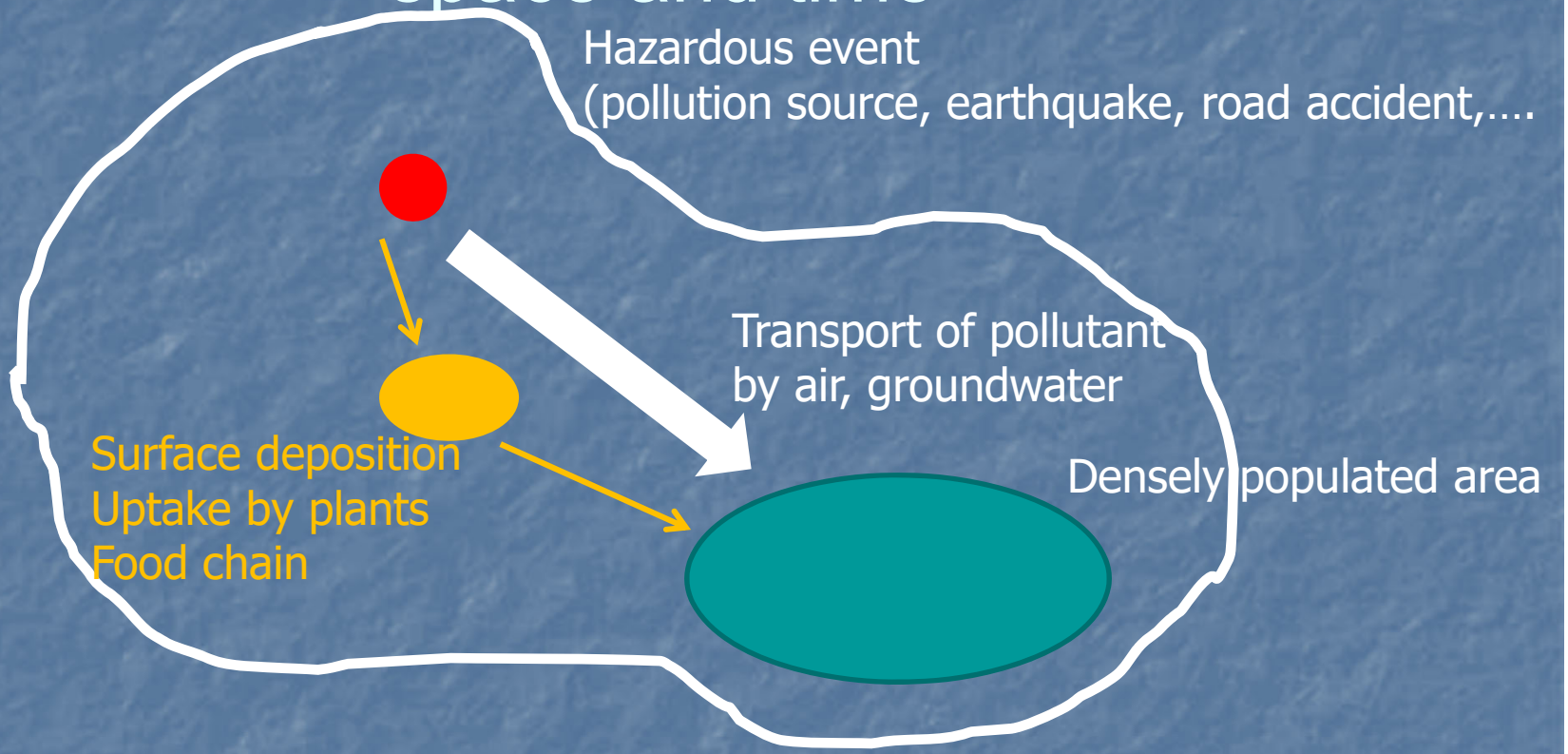
- Here the threshold dose is ρ: the dose below which no health effect can be expected
- $g(\lambda)$ is the probability that the dose is λ
- $DR(\lambda)$ is dose response function

Some extensions

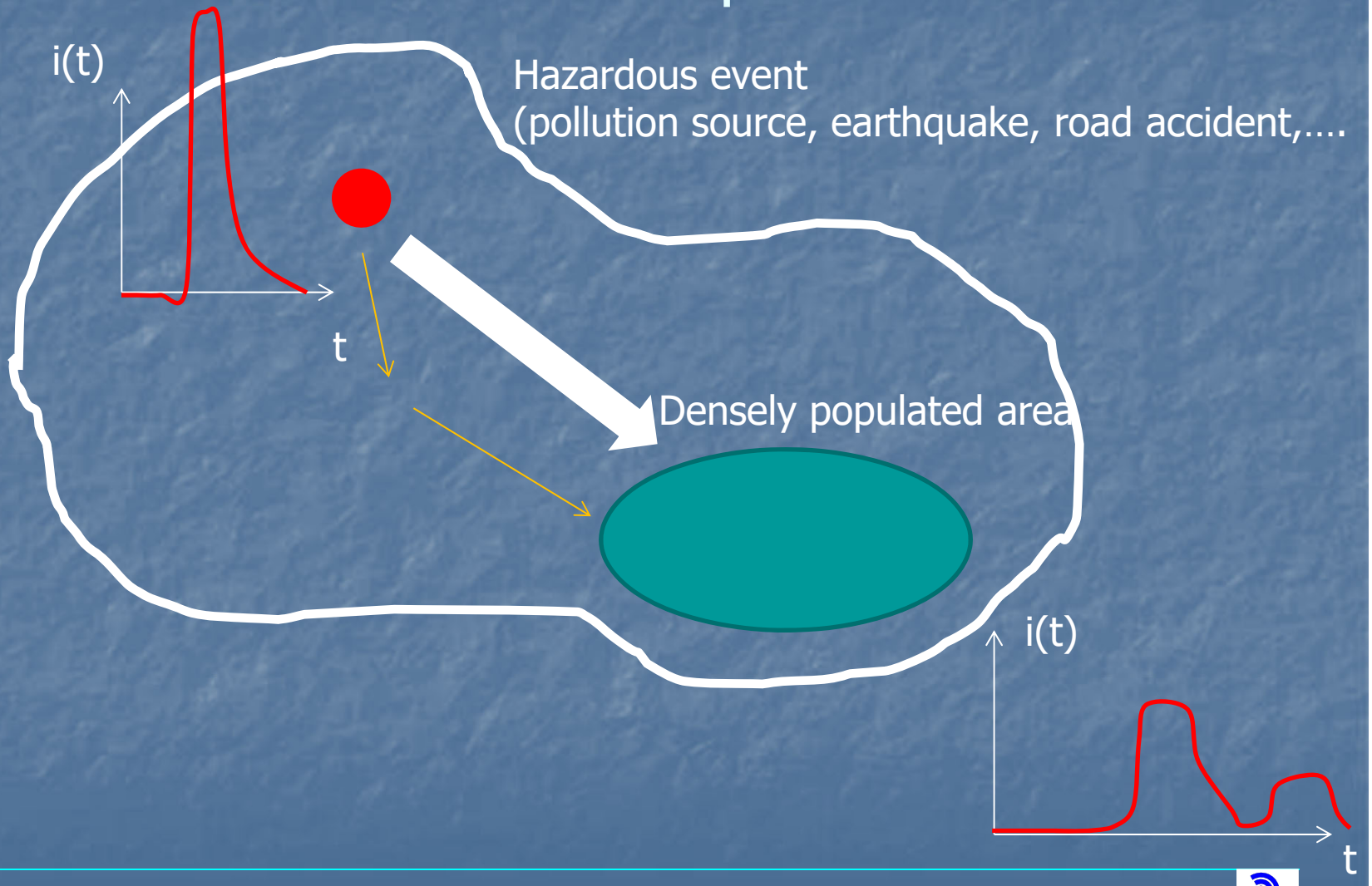
- The origin of the hazardous event is at location x
- The impacts are observed at location y

- A hazardous event occurrs at time t
- The impacts are happening at time t + Δt

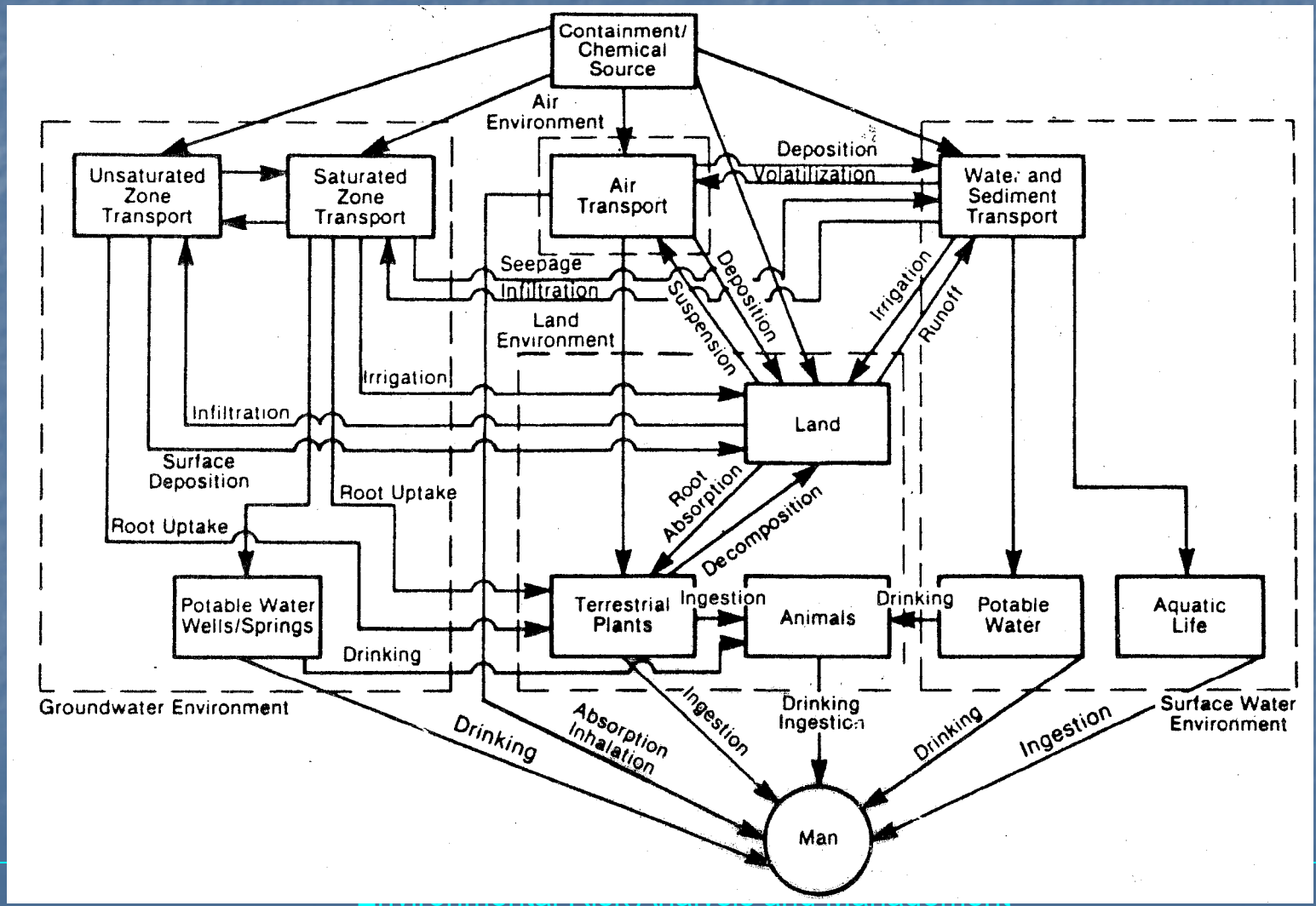
Transfer of hazards (impacts) in space and time



Transfer of hazards in space and time



From source to exposure and to dose: Environmental transport processes



Summary and conclusions

- We characterise a hazardous event by its magnitude and frequency
- We describe the consequences by damages, fatalities, …
- Risk considers both and it is an expectation value
- Different characterisations of risk