1) An Introduction to Systems Analysis

SUMMARY: Introduction to concepts and main characteristics of a system

References: Reading list below, in particular Wilson (1981)
http://sems.auckland.ac.nz/Edu/423.310/bin/lectures_frameset.html?../lecture1/lecture1_text.html

Definition of systems analysis (one of many):
Object of study which is made up of a number of interrelated components.

Aim of systems theory:
To generate a deeper understanding of objects of study. The terms *Systems analysis* and *systems theory* are often used interchangeably, although the latter implies something more specific, applicable perhaps to a particular type of system.

System characteristics: (after White *et al.*, 1992)

- Possess structure or organisation of the components
- Are generalisations, abstractions or idealisations of the real world
- Function in some way
- Functional as well as structural relationships between units
  - Function implies the flow and transfer of some kind of material
  - Function requires the presence of some driving force or source of energy
- All systems show some sort of integration

Systems analysis within science:
There is a lot of confusion about the nature of scientific methods. It is often suggested that the scientist derives general truths from facts – however, is there such thing as a fact? It can be argued that the essence of the scientific method is the construction of *theories* and the testing of these by comparing predictions from them with observations. In essence such testing is an attempt to disprove the theory, i.e. scientists are concerned with attempted falsification rather then direct verification (K. Popper): Theories are never proved to be generally true but only not yet proved false.

Theories start out life as *hypotheses*, a set of propositions which aim to explain the structure of some system and how it develops. I.e. we are interested in pattern (or structure) and process. Such “explanations” may be expressed in a variety of languages, Mathematics being one of them. Explanations can be at various levels. Systematic description is a useful, but very low level of explanation. A high level of explanation is often a theory which contains abstract concepts, however, in this case more is asserted (speculated?) about the world.

Thus a *theory* is usually used to denote a hypothesis which has been tested to a reasonable extent and which can be believed with more confidence. A *law* is a very well tested and established theory. Remember, however, that even the best laws are likely to be revised and replaced in due course. (examples?)

The main task of a scientist is to generate and test theories. There are two fundamentally different approaches:

- *Induction:* The data is studied with the aim to infer more general ideas without theoretical preconceptions ("pure" approach, often used in social sciences).
- *Deduction:* Speculation (in an informed way) on how a system works and construction of a theory accordingly. Deductions are made from this theory which can be tested against observations. Theory is then rejected or revised (more useful approach).

"Applied" systems analysis:

Traditional approach of scientist to study system of interest is *reductionist*: To investigate the individual parts of a system in greatest detail and use the combined knowledge as the basis to solve any problem related to that system. It can, however, be argued that the behaviour of the overall system has a distinct and often important character of its own. In many cases, the behaviour of the whole is very much more than the sum of the behaviour of the parts. (examples?)

In the context of environmental sciences, the systems approach breaks down the highly complex environment into a number of inputs, outputs and discrete components that are interconnected to varying degrees. Because of the overall complexity and large number of individual components, it is practical to select only the significant components and interconnections, all else is neglected.

This approach is based on two assumptions:

- It is possible to subdivide the real world into discrete, contained systems
- It is possible to determine the various inputs, outputs and interrelationships between components

The challenge is:

- To identify the significant components
- Determine the nature of the interconnections

How to understand complicated systems:

- Set up *frameworks to handle complexity*. Can be done through systematic description of object of study, its components and processes.
- Identify *systemic behaviour*, i.e. behaviour of system is different from what is predicted as the sum of its parts (high level of interdependence).
- Seek *generality*; whether methods of analysis from one system can be applied to others.

Properties of systems:

- Open and closed: Open – Closed – Isolated
- Steady-state: Over some suitable time interval state of the system remains the same. System may vary about this mean state. Systems may have more than one steady state, therefore if perturbed may move to a new steady state.

- Dynamic equilibrium: A steady-state situation in which a reverse process is occurring at such a rate that it exactly balances the corresponding forward process. Steady-state which involves cyclical variability.
- Stability: Tendency to return to a steady state once the system has been perturbed from it. If a small perturbation causes the system to move back towards (further away from) the original state then the system is said to be stable (unstable).
- Feedback: Negative - positive

Readings:

Chapman (1977): Chapters 4 and 10

Chorley and Kennedy (1971): Chapters 1 and 8

Gregory (1985): Chapter 7

Harvey (1969): Chapter 23

Huggett (1980): Chapter 1

Wilson (1981): Chapters 1 and 2