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To prevent a repetition of the costly experiences with leaky waste disposal sites in the Molasse, it will be necessary to conduct sound environmental risk assessment studies prior to the construction of new landfill sites (to provide constraints on technical barrier design) and to implement follow-up ground water monitoring. Preconstruction risk assessment should include the provision of reliable geological and hydrogeological information, with emphasis on finding locations with suitable natural barriers. It will also be necessary to identify geological features that could affect the ground water flow if the technical and natural barriers are breached (e.g. major fractures or porous sands). To understand the impact of the system "Fill-Liner-Bedrock" it will be necessary to have base-line information with which to compare the results of the geochemical and hydrogeological monitoring of the landfill. Such reference data should be collected prior to the establishment of the landfill site.

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Waste Disposal in Molasse Sediments: Elements of uncertainty in the safety assessment

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The Kölliken hazardous waste landfill has been operated from 1978 to 1985. During this time, around 300 000 m^3 of waste were dumped into the former clay pit. The geology beneath and adjacent to the landfill was investigated with close to 100 boreholes. The subsurface is Lower Freshwater Molasse, mainly variegated shales, clays and sandstone beds. The uppermost 40 m are a succession of fluviatile, lacustrine and terrigenous environments.

For the assessment of the landfill's safety, a hydrogeological model was developped already in early phases of the project. Correlations of the different formations showed rock layers with a very strong anisotropy in hydraulic conductivity. The relationship between the geological body size and the relevant flow distances made obvious that averaging of hydraulic parameters would lead to incorrect results. Observations of the hydraulic heads showed an upward gradient, causing infiltration into the landfill. With ongoing investigations, the model became increasingly sophisticated. With the new geologic data and additional information in other domains, e.g. clay-organics interaction, it became necessary to revise the initial safety assessment, dating from the early seventies. When reviewing the latter, three systematic types of error could be identified:

- errors caused by early stage simplifications of the geological reality,
- measurement errors in hydraulic testing, and errors in predicting dynamic process development with time,
- errors due to lack of advanced knowledge.

In conclusion, it was recognized that in safety assessments uncertainties have to be clearly accounted and, as far as possible, quantified. The main question to answer is: How close is my result to the ideal, complete safety assessment?

Finally, it was concluded that safety assessments for landfills, with impacts covering long future timespans, have to be periodically checked, because they tend to become obsolete with new advances in general knowledge.

Disposal of radioactive waste in the Lower Freshwater Molasse

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Nagra's investigations relating to the disposal of high-level radioactive waste in deep rock formations have been extended to cover sediments in addition to the crystalline basement. By way of complying with a governmental directive, Nagra has, since the completion of Project "Gewähr" in 1985, intensified its studies in sedimentary formations. Based on a comparative assessment of potential host rocks (Permian, Anhydrite Group, Gipskeuper, Opalinus Clay, Effingen Beds, Lower and Upper Freshwater Molasse), the Lower Freshwater Molasse (Untere Süsswassermolasse – USM) and the Opalinus Clay (Opalinuston OPA) were selected as the most promising options. Engineering, hydrogeology and safety aspects of these two formations were then investigated. The safety analyses indicated that, from a present-day viewpoint, safe disposal would be possible in both these host rock options. However, the incompleteness of the available database necessitated making certain assumptions which contain a relatively large element of uncertainty. The results of all these studies were published in the series of the Nagra Technical Reports (e.g. NTB 88-25, NTB 88-25E, NTB 91-19).

For the Opalinus Clay a seismic survey is being carried out in winter 1991/92 in a selected region in northeastern Switzerland and further studies have been started.

For the USM, a study programme has been initiated. Additional unpublished data, e.g. from the oil industry (seismic lines, borehole data), have to be procured and analysed. The main questions to be answered in this programme are:

- Is it possible to locate with the existing data tectonically "quiet" areas in the Swiss Plateau with marl-rich formations of sufficient extent and thickness?

  If yes, where are these areas?