NUCLEAR SAFETY AND RELIABILITY

WEEK 10

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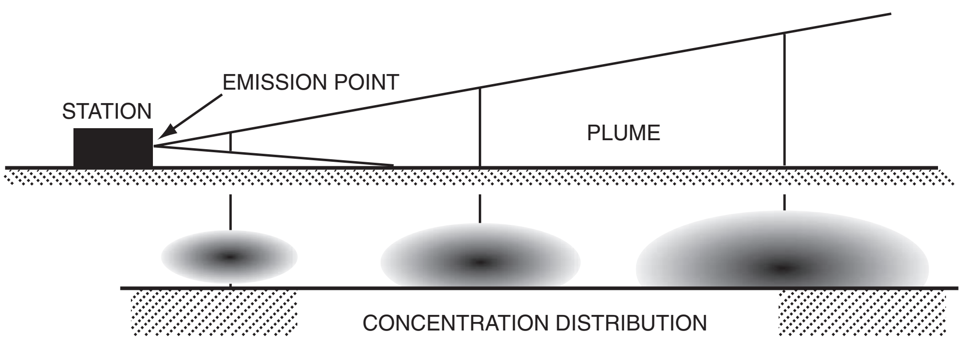
Radioactive Materials Dispersion In The Environment

This material is reasonably well covered in Chapter 11, Section 11.4 of LaMarsh. Dispersion calculations are based on observed atmospheric stability characteristics (the so-called Pasquill conditions), an assumed wind speed, and a simple mixing model. The method used is the Gaussian plume model, which also is applied in most non-nuclear atmospheric contamination calculations. The model is only a very rough approximation of the real case, and for application must be modified by several empirical correlations. The reason for using such a model is that the actual dispersion of pollutants in the atmosphere is too complex to be modeled realistically.

Figure 10.1 shows a rough schematic of a plume discharge according to this model. The plume initiates at a point at some defined height, and disperses uniformly until it intersects with the ground surface. Dispersion then continues downwind with ever-decreasing concentration and increasing width. A "puff" discharge is modeled as an emission with finite width. Steady leakage is modeled as a constant discharge. Ground fallout from the plume is represented by a "deposition velocity" for each radioactive species. The deposition velocity is determined by particle size, chemical reactions in the atmosphere, and by local precipitation.



Main factors determining dose rate at a point on the surface:
- Concentration and characteristics of radionuclides
- Distance from emission point
- Distance from centre of plume
- Wind speed
- Deposition rate

FIGURE 10.1 — POST-ACCIDENT PLUME EMISSION (GAUSSIAN MODEL)

Since the Gaussian model does not account for air turbulence and interaction with surface features, it underestimates the rate of widening of the plume and overestimates its local concentration. Experimental data are used to correct the diffusion model. Additional turbulence is induced by the building wake; mixing is therefore increased close to the source. The "effective height" and dispersion of the release are determined by atmospheric conditions and the temperature of the released gases. For example, dispersion after the Chernobyl accident was strongly affected by high gas temperature, which lifted radioactive materials into the upper atmosphere, and by an inversion layer at approximately 2km altitude. These effects reduced the dose rates in the immediate vicinity of the plant and increased the rates far from the plant. Local rainfall produced patches of high ground contamination in parts of the Ukraine tens of kilometers from the accident.

Calculation of Expected Radiation Doses Following an Accident

This material is covered in Section 11.5 of LaMarsh. The calculation methods are adapted directly from those used in Chapter 9, Sections 9.9 to 9.11.

Dispersion and dose calculation methods for use in Canadian reactor licensing proceedings have been standardized in CSA-N288.2. This is still a Draft standard, but has been accepted by designers, operators, the Atomic Energy Control Board, and Environment Canada for interim use.

Dispersion and dose calculations are useful only for prediction of consequences before the fact, and for setting up emergency response plans. In the event of a real accident, the key action for protection of the public is measurement of the concentration and distribution of radioactive materials. Only after these measurements can the appropriate emergency response be established. Radioactive contamination is easily measured in the field with portable instruments; this gives the radiation-accident response team an advantage which does not exist in many other emergency situations.

Emergency Planning

The operator of a nuclear power reactor in Canada must establish an emergency plan satisfactory to local, provincial, and federal authorities. This rule was established in 1962, when the first CANDU prototype (NPD) came into operation. Figure 10.2 shows the major components of the post-accident consequence model. Before the accident, estimates are made of the likely consequences for the major accident categories. Immediately following an accident, the most important action is measurement of actual dose rates in and around the plant, so as to determine what needs to be done. These actions are carried out by station staff; a typical action sheet taken from an emergency procedures manual is shown in Figure 10.3. Station staff and management retain responsibility for on-site actions in the longer term, and off-site actions are transferred to the provincial authorities (EMO in New Brunswick). A typical emergency notification table is shown in Figure 10.4. The longer-term actions and responsibilities are shown in Figure 10.5. Actions required of the surrounding population range from "stay-in" advisories to large-scale evacuation, depending on the results of field dose rate surveys.

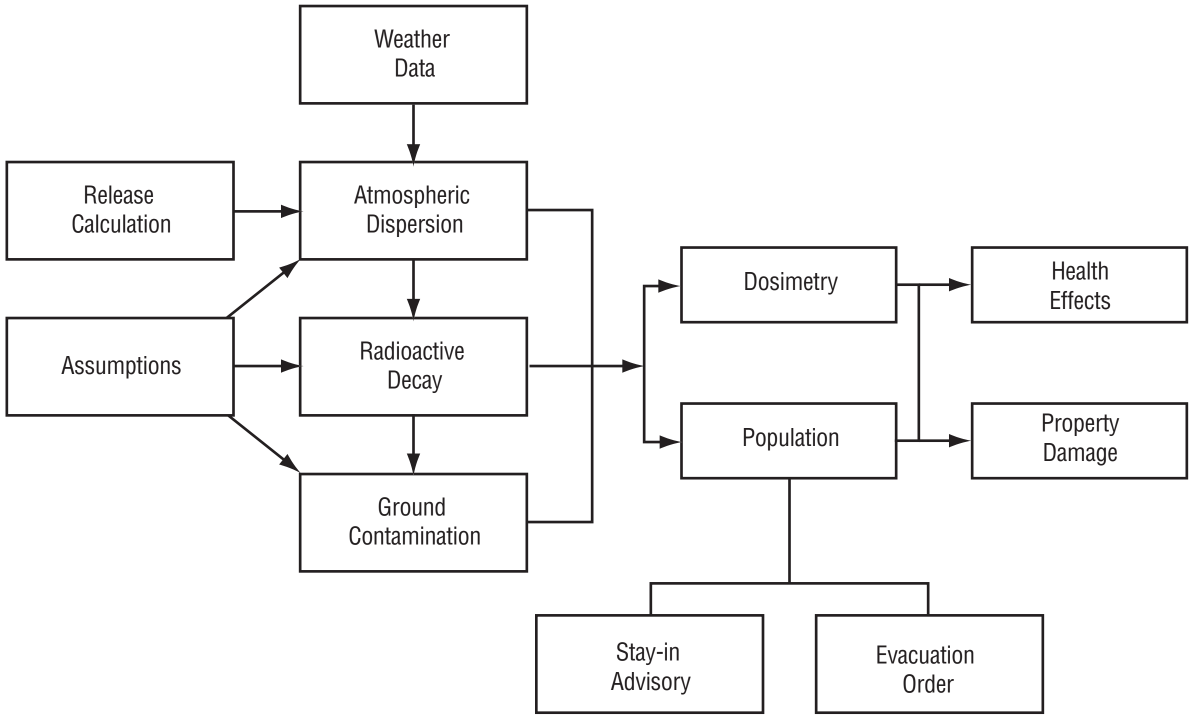


FIGURE 10.2 — COMPONENTS OF CONSEQUENCE MODEL

Agreed action levels are an essential part of any emergency plan. The Ontario PAL's are shown in Figure 10.6. These values are either estimated immediately by station staff or derived from the environmental survey results.

This completes the qualitative discussion of LOCA accident analysis begun in Week 8.

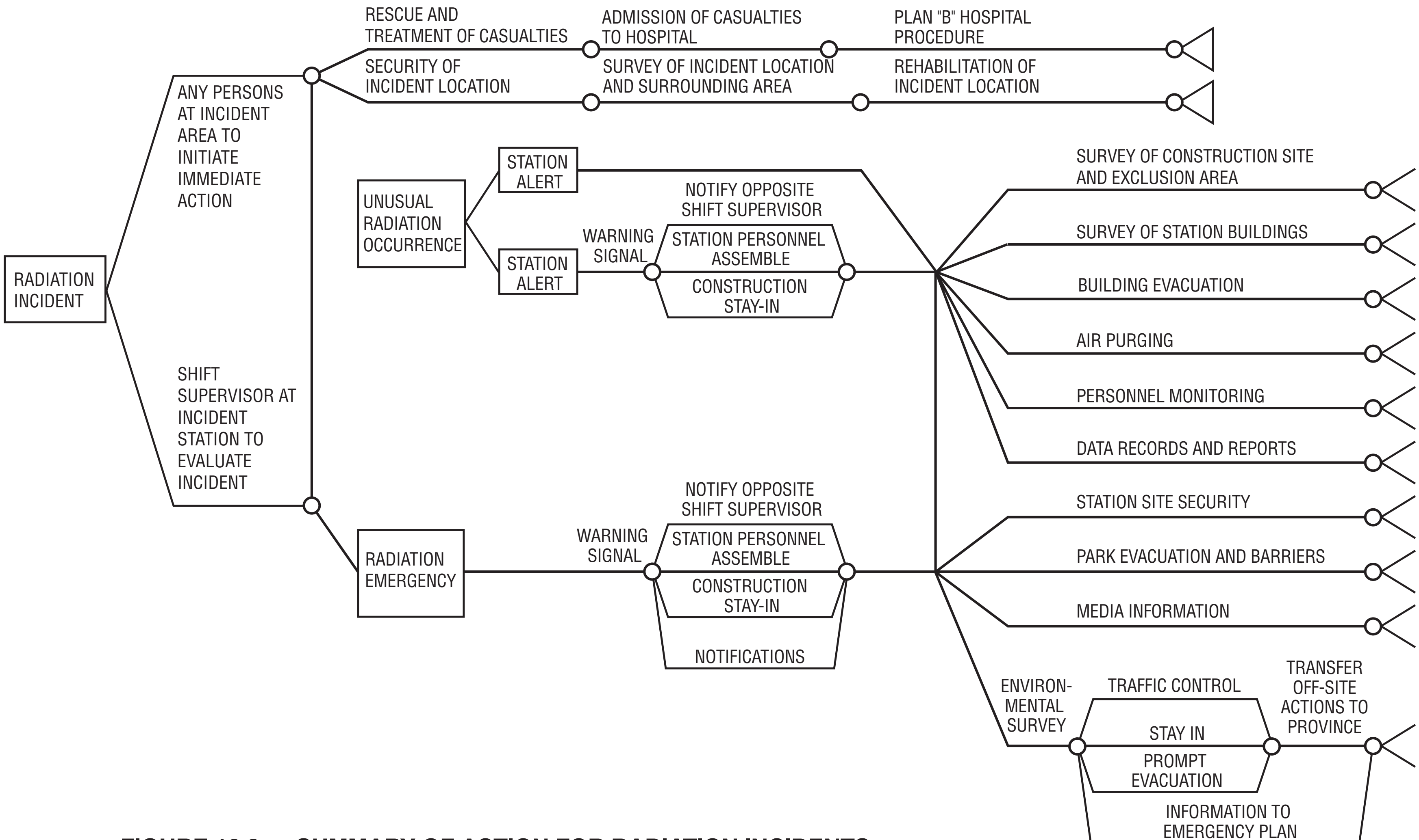
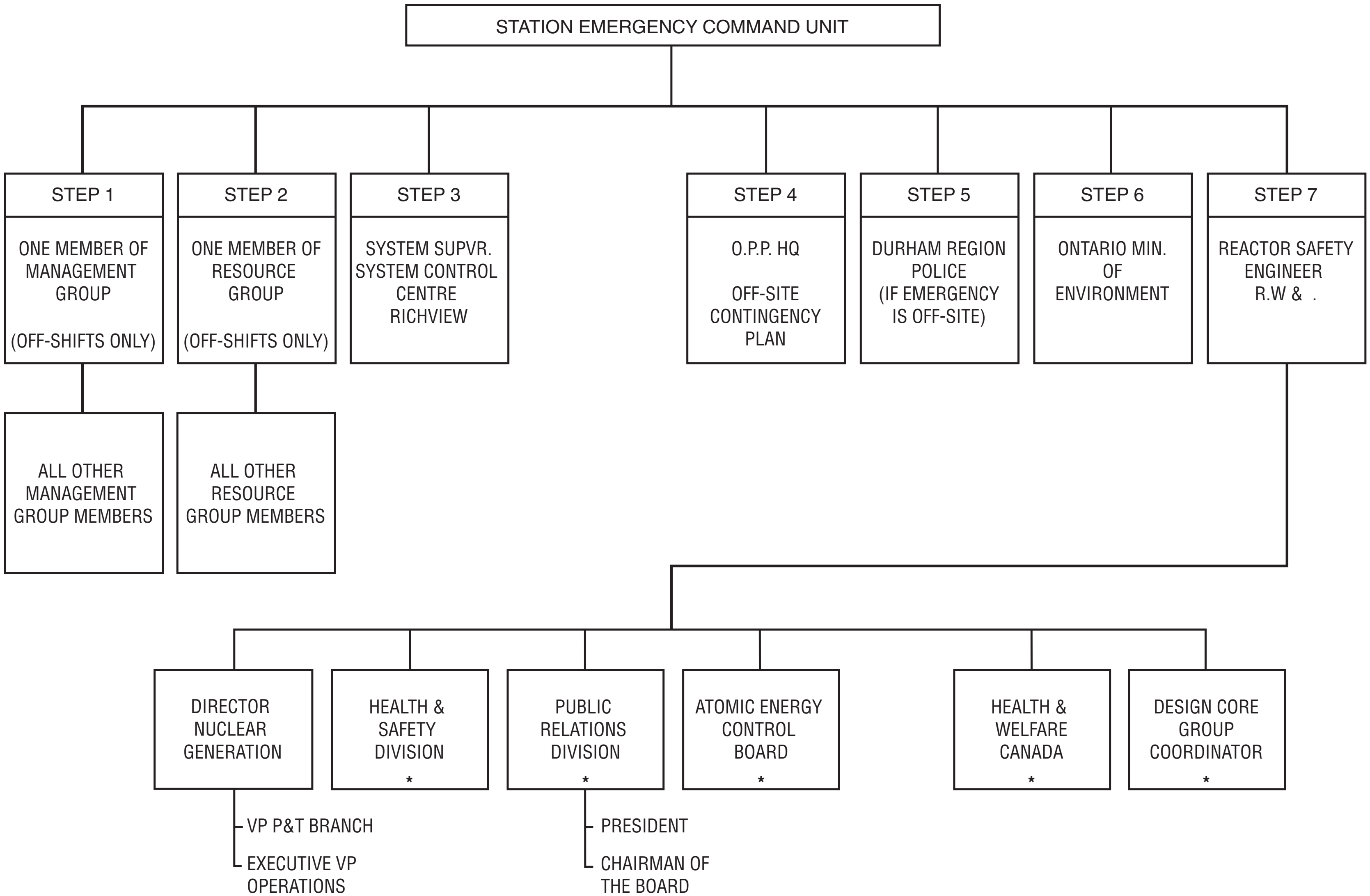


FIGURE 10.3 — SUMMARY OF ACTION FOR RADIATION INCIDENTS



* The official telephoned will be responsible for making any further appropriate notifications within their organization.

FIGURE 10.4 — EMERGENCY NOTIFICATION TABLE

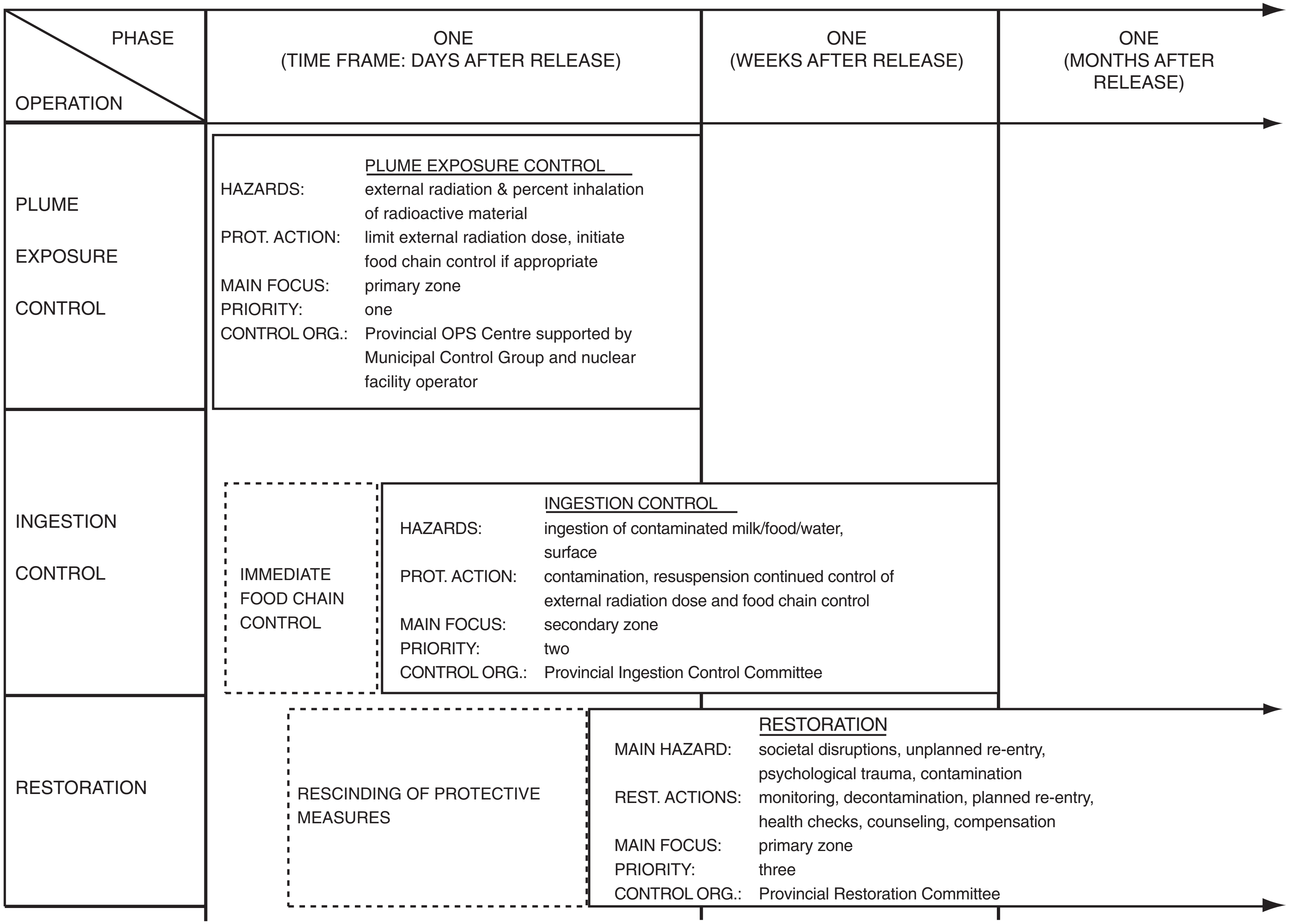


FIGURE 10.5 — CONCEPT OF OPERATIONS

Figure 10.6
Protective Action Levels (PAL's)

The following Protective Action Levels will be used in Ontario:

Measure	Lower Level		Upper Level	
	Effective	**Thyroid**	**Effective**	**Thyroid**
Sheltering	0.1 rem	0.3 rem	1 rem	3 rem
	(1 mSv)	(3 mSv)	(10 mSv)	(30 mSv)
Evacuation	1 rem	3 rem	10 rem	30 rem
	(10 mSv)	(30 mSv)	(100 mSv)	(300 mSv)
Thyroid Blocking	------	10 rem	------	50 rem
		(100 mSv)		(500 mSv)
Banning Food/Water	0.05 rem	0.15 rem	0.5 rem	1.5 rem
	(0.5 mSv)	(1.5 mSv)	(5 mSv)	(15 mSv)