Capability Statement
Sub-Sea Modelling Services

MMI Engineering has developed a bubble plume model to assess the impact of a sub-sea release of gases - including hydrocarbons and hydrocarbon gases and CO_2 - from a pipeline at intermediate depths (30m and 100m).

Hydrocarbon gases and CO_2 may be in different states in a pipeline - hydrocarbons will be in the vapour phase, but CO_2 may be vapour or dense phase fluid. However, on release the CO_2 will rapidly expand to the vapour, and both cases will result in an upwardly flowing plume driven by the bubble buoyancy.

Ambient seawater is entrained into the bubble plume by the action of shear and turbulent eddies, resulting in a two phase plume (see Figure 1). The water plume is wider than the bubble plume and, at the depths considered for the study, unstratified. At present, the plume model does not account for sea currents which would increase the complexity of the analysis significantly.

An important aspect for the numerical modelling of the plume is that the flow can be considered to be self similar - essentially the flow evolves in a kind of self-governing equilibrium. Thus, plume properties may be described fully by a centreline value and a characteristic radius, both of which vary with height. In a similar approach to atmospheric dispersion modelling, Gaussian shape profiles are assumed for the time averaged water plume velocity and the void fraction (the fraction of the plume cross-sectional area occupied by bubbles) enabling the development of governing differential equations. These equations account for volume conservation (i.e. turbulent entrainment) and momentum conservation (buoyant forces).

For the particular case of CO_2, or other gases which will dissolve in seawater, a third equation models the dissolution of the gas bubbles. This can be a significant effect in some cases in which the bubble plume may even dissolve entirely, resulting in a single phase plume of seawater only. Where relevant, the environmental impact of a CO_2 release is assessed by the pH of the water plume calculated from analysis of the solution chemistry of carbon dioxide in the seawater.

The equations governing the flow are integrated using a 5th-order adaptive Runge-Kutta algorithm, given appropriate calculations and estimates of initial conditions. The initial bubble mass flow rate is calculated using Bernoulli's equation for small hole releases while a separate pipeline blow-down model is used for the full-bore release cases. The initial void fraction and plume width are estimated a small distance from the release point where self-similar behaviour is expected i.e. not within the region where the dominant effect is the expansion of the supercritical CO_2 into a gas phase.

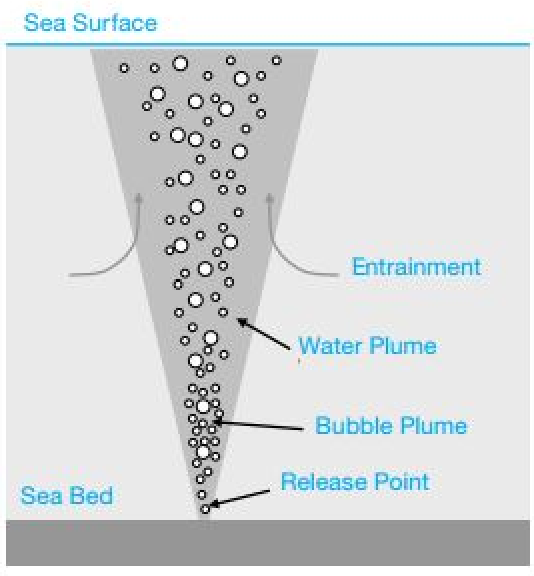

Figure 1: Diagram of the bubble plume