Recognition of Current Gathering Responses:

West and Edwards (1985) have shown by studying the response of a disk inhomogeneity in a conductive half space that to calculate the scattering current, direct interaction between the scattering current and the eddy currents they induce in the host medium may be neglected to a first order approximation. These static or DC solutions suggest that in the case where the body is reasonably compact, and the primary electric field has the same general direction throughout, then as long as the target's 'skin effect' does not dominate, current gathering 'anomalous' current density $Jg^S(r',t)$ may be written from magneto metric response solutions (eg. Edwards, 1974) as,

$$Jg^s(\underline{r}',t) = C \underline{E}^P(\underline{r}',t) \quad -(2)$$

where C is a conductivity contrast/geometrical (body shape) function.

The current gathering 'anomalous' current density will then essentially have the time dependence of the primary electric field in the vicinity of the body. Therefore, as long as the 'late' time free space approximation from the previous section is valid, the magnetic field will have the same time dependence. To study this time dependence, electric field in a half space solutions from Lewis and Lee (1978) and Silic (1987) are used.

It is shown that for step TDEM systems (eg. UTEM, West et al, 1984) at 'late' times when $(a^2 + z^2 + r^2) \frac{\sigma\mu}{4t} \ll 1.0$ where a is the loop radius, r is the distance from the loop centre and z is the depth,

$$\underline{E}^P(r,z,t) = \frac{a^2r}{40\sigma\sqrt{\pi}} (\frac{\sigma\mu}{t})^{5/2} + \frac{5a^2rz\Gamma(5/2)}{480\sigma\sqrt{\pi}} \sqrt{\frac{\sigma\mu}{4t}} (\frac{\sigma\mu}{t})^{5/2} \quad -(3)$$

while for the impulse systems (Buselli and O'Neill, 1977; McNeill, 1982)

$$\underline{E}^P(r,z,t) = \frac{a^2r}{16\sigma^2\sqrt{\pi}} (\frac{\sigma\mu}{t})^{7/2} + \frac{a^2rz\Gamma(5/2)}{32\sigma^2\sqrt{\pi}} (\frac{\sigma\mu}{t})^4 \quad -(4)$$

Essentially at 'late' times the step system electrical field is characterized by a $t^{-5/2}$ power-law decay, while the impulse system's electric fields will have a $t^{-7/2}$ time dependence. To determine whether current gathering effects are dominating the response, a power law decay is fitted with care to the latest anomalous times. If this power law then dominates the response for most of the anomalous time, and its exponent depending on the system is close to -5/2 or -7/2, then current gathering effects may be inferred.

It is also recognized from Kaufman and Keller (1985), that the 'very late' time inductive effect, when the vortex currents in the conductive target are following the decay of the half space magnetic field, will also have a $t^{-5/2}$ or $t^{-7/2}$ power law decay. However, this effect may only be important for thick or relatively flat-lying targets since the direction of the half space primary magnetic field is relatively vertical at the 'late' times. However, unlike the current gathering effect, it begins as a 'very late' time phenomena. As such it is not expected to dominate the response for most of the anomalous time.

Interpreting Spatial Derivatives of Fixed Loop TDEM Data

Different interpretation methods must be used for current gathering anomalies than for vortex current induction responses. The strength of a current gathering effect is a function of conductivity contrast between the anomalous body and the host medium, the body's geometry and the conductivity of the half space, whereas the time dependence of the response is largely a function of the host medium's primary electric field. The latest time at which the anomalous response will be detected, will therefore be largely a function of the maximum amplitude of the magnetic field at early time, this also being a function of depth or distance to the conductor. Therefore, discriminating techniques which rely on conductivity-thickness estimates from decay analysis, or the latest time affected by a conductor, are not valid for current gathering responses.

This section looks at the problem of attempting to obtain the shape of the conductive source from spatial derivative data, and its implementation as a discriminating technique. It is reasoned that if the shape of the target can be estimated from the profile data, then we may discriminate between the conductive bodies on the basis of their interpreted geometry.

1: Theoretical Considerations

By using the approximation discussed in the previous section that at 'late' times free space Green's tensors may be used in equation 1, considerable simplication results in evaluating the potential field problem which links the magnetic field components to a current distribution. In this section, only results for 2-D bodies will be discussed. Formal solutions have been obtained for arbitrary current distributions within dipping sheets and blocks; however only some of the formal solutions for a dipping current sheet will be presented, as they have a similar, but simpler form to block conductor formulations (Silic, 1989). More complex shapes can be modelled by a superposition of a number of blocks and sheets. By assuming that a current density distribution can be expressed as a polynomial, then analytical solutions for the vertical (Hz) and horizontal (Hx) field components are obtained using Gradshteyn and Ryzhik (1980). Furthermore by manipulating the integral equation which links the magnetic field components to a current density it is shown (Silic, 1989) that the first and second horizontal spatial derivatives of the magnetic field components are related through a set of geometric functions to the current density and its first spatial derivative at the edges of the conductor. As a result a number of simple relationships between the first and second derivatives of the magnetic field components and the edges of the conductive units are obtained. For example, for relatively uniform current flow in a current sheet

$$(\frac{\partial Hz}{\partial x})^2 + (\frac{\partial Hx}{\partial x})^2 = \frac{J(o)^2}{x^2+h^2} + \frac{J(L)^2}{(x_L^2+h_L^2)} \quad -(5)$$

where J(O) and J(L) are the current densities at the respective edges of the sheet, while x, h and x_L, h_L, are the horizontal and vertical distances to the edges. This function is completely