BEST PRACTICES IN ELECTRICAL RESISTIVITY IMAGING: DATA COLLECTION AND PROCESSING, AND APPLICATION TO DATA FROM CORINNA, MAINE

An Administrative Report for EPA Region 1

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SUMMARY

This administrative report documents “best practices” for the collection and analysis of electrical resistivity imaging (ERI) data and presents a demonstration of these best practices at the Eastland Woolen Mill Superfund Site, Corinna, Maine. With recent advances in ERI technology and software, the state-of-the-art for data acquisition and analysis has evolved rapidly. Practitioners are faced with numerous choices in selecting acquisition and inversion parameters, some of which can affect results substantially. Here, we propose a series of guidelines to (1) enable the design of robust survey geometries, (2) inform selection of acquisition and inversion parameters, and (3) document proper data collection, quality-assurance and quality-control, and analysis procedures. Although this report focuses on cross-hole ERI, the guidelines presented are, in many cases, also relevant to ERI conducted with electrodes at ground surface. We use these guidelines to collect, analyze, and interpret data from the Corinna site. Our experimental results indicate only weak correlation between resistivity anomalies and hydraulic features identified previously in borehole logs. Based on analysis of reciprocal data and inversion sensitivity, the Corinna dataset contains substantial noise and error.

1. BACKGROUND ON ELECTRICAL RESISTIVITY METHODS

Electrical resistivity imaging (ERI) is a direct-current (or low-frequency alternating-current) method that can be used to estimate the distribution of electrical resistivity under the assumption of electrical isotropy and scalar quantities in the subsurface. Bulk resistivity is directly related to rock type, porosity, ionic strength of the pore fluids, and surface conductivity of geologic materials. Although water in its pure state is non-conductive, the presence of chemical salts in solution produces a conductive electrolyte detectable with resistivity methods (Zohdy and others, 1974). ERI is therefore sensitive to the presence of moisture, changes or contrasts in ionic strength of pore fluids, porosity, and lithology.

To collect the requisite resistance measurements in the field, a series of electrodes are attached to a resistivity control unit, which consists of a current source (for example, deep-cycle battery), voltage meter, current meter, and multiplexers for multi-channel data collection. Electrodes are commonly stainless-steel or graphite. Steel electrodes tend to be more durable, whereas graphite electrodes resist corrosion.

Resistance data are collected by establishing an electrical-potential difference between two source electrodes and measuring the resultant potential distribution at two or more receiving electrodes. This procedure is repeated for as many combinations of source and receiver electrode positions as desired, and usually involves the acquisition of many hundreds or thousands of multi-electrode combinations.

For a given current, the voltages between one or more pairs of electrodes are measured. The physics underlying ERI is described by the Poisson equation:

$$\nabla \cdot \sigma \nabla \phi = I\delta(x - x_s, y - y_s, z - z_s) \tag{1}$$

subject to boundary conditions, where

σ is the electrical conductivity, an instrinsic property of the material;
ϕ is the electrical potential;
I is the electrical current source;
δ is the Dirac delta function;
x ,y, z are the spatial position vectors; and
x_s, y_s, z_s are the spatial coordinates of the current source.

Equation 1 can be solved as the forward problem for potentials, which would be measured in the field. It is possible to calculate resistance as the difference in potential (i.e., voltage, V) divided by the applied current. Equation 1 assumes equilibrium electrical conditions and includes neither transient effects (induced polarization) or current sources other than electrodes (e.g., spontaneous potentials). For efficient inversion of two-dimensional (2-D) cross sections, it is common to simulate three-dimensional (3-D) current flow under the assumption of 2-D heterogeneity (LaBrecque and others, 1996).

Each measured resistance is a function of the electrical properties of both solids and liquids in the system (Keller and Frischknecht, 1966). Resistance is not an intrinsic property of a rock or soil; rather, it depends on the geometry of, and distance between, electrodes used for measurement. For example, the resistance across 100 m of homogeneous copper wire would be 100 times the resistance across 1 m of the same wire. The relevant intrinsic property is resistivity, ρ, (or its reciprocal, electrical conductivity, σ) where $\rho = KV/I$ and K is the geometric factor describing the measurement configuration, as explained in detail in Section 2. It is important to note that the raw measurements made by resistivity instrumentation are voltages, which are divided by the applied current to produce resistance values. Various software packages take as input resistance data or apparent resistivity data.

In field surveys and in the presence of heterogeneity, the volume of earth sampled by a particular resistance measurement is unknown, and conversion from resistance to resistivity requires inverse modeling. Depending on the survey geometry (i.e., number and placement of electrode cables), inversion can produce 2- or 3-D tomograms, where each tomogram shows the subsurface distribution of electrical resistivity. Electrical imaging is possible at the sub-meter to tens-of-meters scale in practical field-scale investigations, and can be used to reveal static properties such as subsurface structure, as well as temporal changes in moisture and (or) pore fluid salinity. The depth of penetration of the current depends on the electrical resistivity of the subsurface, the spacing of the electrodes, and local noise, and is, therefore, difficult to quantify exactly or to predict prior to data collection and analysis. Many surface studies, however, successfully image resistivity to depths of a few tens of meters below ground surface, and cross-well studies commonly use wells with offsets of similar scale.

ERI has a number of advantages over other geophysical methods for hydrological studies: (1) many hydrological features, such as clay layers, variable moisture content, high salinity, etc., manifest detectable resistivity contrasts; (2) instrumentation is relatively inexpensive, robust, and easy to operate; (3) instrumentation, particularly for surface imaging, is mature and available commercially; and (4) resistivity measurements are amenable to automation, allowing for long-term, continuous, cost-effective monitoring. Resistivity imaging suffers from a number of disadvantages, however, including (1) direct contact with the subsurface is needed, which is problematic in areas with resistive ground cover such as highways, permafrost, etc.; (2) electrode array deployment requires significant labor, particularly for long (several 100 m) arrays; (3) depending on instrumentation and number of electrodes, data collection can be slow and can limit monitoring of rapid dynamic processes; and (4) processing of data, despite commercially available code, requires substantial user knowledge if quantitative, rather than qualitative, interpretation of hydrogeologic processes is required. Currently, there exists no American Society for Testing and Materials (ASTM) or community-accepted quality assurance and quality control (QA/QC) standards for electrical resistivity tomography, hence the need for the best-practices guidance documentation presented here. Below, we outline a set of best practices for ensuring, to the extent possible, high-quality ERI data and inversions that can be used to estimate hydrologic properties and processes.

2. SURVEY DESIGN

Historically, ERI data were collected using a fixed set of geometries (for example, Wenner, Schlumberger, or dipole-dipole arrays) because scientists moved the two current and two potential electrodes by hand, and used simple geometries where analytic methods could be used to estimate the subsurface resistivity without complex inversion (for example, Zohdy and others, 1974). Such work was highly labor-intensive and time-consuming. Although there remains considerable labor involved in initial deployment of cables, the advent of multi-node cables (i.e., cables with tens of electrodes) and multi-channel instrumentation enables much faster data collection. Furthermore, modern inversion software is capable of processing ERI data in minutes on a low-end PC, and does not require that electrode arrangement correspond to any of the traditional, standard array types (for example, Schlumberger, Wenner, dipole-dipole). Whereas selection of an ideal geometry has been the subject of past research (Furman and others, 2003, 2004; Stummer and others, 2004), the ability to resolve properties in the subsurface is dependent on the electrical conductivity of the subsurface, which is unknown (Day-Lewis and others, 2005). For cross-well tomography, where the electrodes are deployed within a series of wellbores, we suggest the use of a mixed survey geometry combining in-well and cross-well dipoles; i.e., with current pair in one well and potential pair in a second, as well as with current and (or) potential pairs split between wells. In-well dipoles are sensitive to targets located near boreholes, but do not provide much information farther from boreholes. On the other hand, cross-well dipoles are more sensitive to targets located farther from wells (Day-Lewis and others, 2007). The combination of these geometries provides an effective coverage of the subsurface; however, the number of possible combinations of quadripoles, given *n* electrodes, is $n!/(n-4)!$ which is far too many measurements to possibly collect in the field given the memory constraints of most resistivity meters and the time required to collect the data. Depending on the instrument used, how quickly it can acquire data, and the decision whether or not to collect time-lapse data, we select an appropriate number of quadripoles given two criteria: geometric factor and accuracy of forward modeling. We note that in order to collect quality cross-hole data, the boreholes should be twice as deep as they are far apart. Also there is a limit on the wellbore spacing that is governed by the resistivity of the earth materials and the capability of the equipment to inject current.

2.1. Selection of geometries with small geometric factors

We introduce the concept of the geometric factor in the context of surface arrays, rather than cross-hole arrays, because the underlying math is simpler and we expect many readers are already familiar with surface arrays. Assuming a homogeneous half space, the geometric factor, *K*, for every quadripole involving current electrodes *A* and *B* and potential electrodes *M* and *N*, is calculated for surface arrays using the well-known equation:

$$K = \frac{2\pi}{\frac{1}{\overline{AM}} - \frac{1}{\overline{AN}} - \frac{1}{\overline{BM}} + \frac{1}{\overline{BN}}}, \qquad (2)$$

where $\overline{AM}, \overline{AN}, \overline{BM}, \overline{BN}$ are the distances between electrodes *A* and *M*, *A* and *N*, *B* and *M*, and *B* and *N*, respectively. The geometric factor accounts for the arrangement of electrodes and allows one to calculate an apparent resistivity, ρ_a, from measured resistance data, as $\rho_a = K\ V/I$, assuming a homogeneous earth. Of course, were the earth homogenous, we would not need geophysics, so this assumption is never met. Nonetheless, it is useful to consider apparent resistivity, which, having the same units as the intrinsic property being estimated, is more intuitive and easily examined for error than raw resistance values (V/I).

For cross-hole geometries, the electrodes are located within the half-space rather than at the boundary at the earth's surface. In this case, use of equation 2 would not account for the no-flow condition at the earth's surface. To account for the effect of the boundary on cross-hole measurements, the "method of images" from optics is commonly invoked. This approach is analogous to the use of "image wells" in ground-water hydrology for analytical modeling of aquifer response to pumping. Here, imaginary "image electrodes" are introduced on the other side of the boundary, equidistant from the real current electrodes, to mathematically produce a no-flow condition at the earth's surface:

$$K = \frac{4\pi}{\frac{1}{\overline{AM}} + \frac{1}{\overline{AM}_{image}} - \frac{1}{\overline{AN}} - \frac{1}{\overline{AN}_{image}} - \frac{1}{\overline{BM}} - \frac{1}{\overline{BM}_{image}} + \frac{1}{\overline{BN}} + \frac{1}{\overline{BN}_{image}}} \qquad (3)$$

where "*image*" indicates image electrode.

Quadripoles with large geometric factors may produce small voltage differences, which are prone to error. In other words, the conversion of measured voltages to apparent resistivity is subject to larger error for data with high geometric factor. A critical cutoff is determined based on the average expected electrical conductivity of the field and the instrument specifications. Figure 1 illustrates how error in measured voltage translates into error in calculated apparent resistivity as a function of K, holding I constant at 50 mA and assuming a 1-microvolt (μv) instrument error. In practice, larger errors may occur.

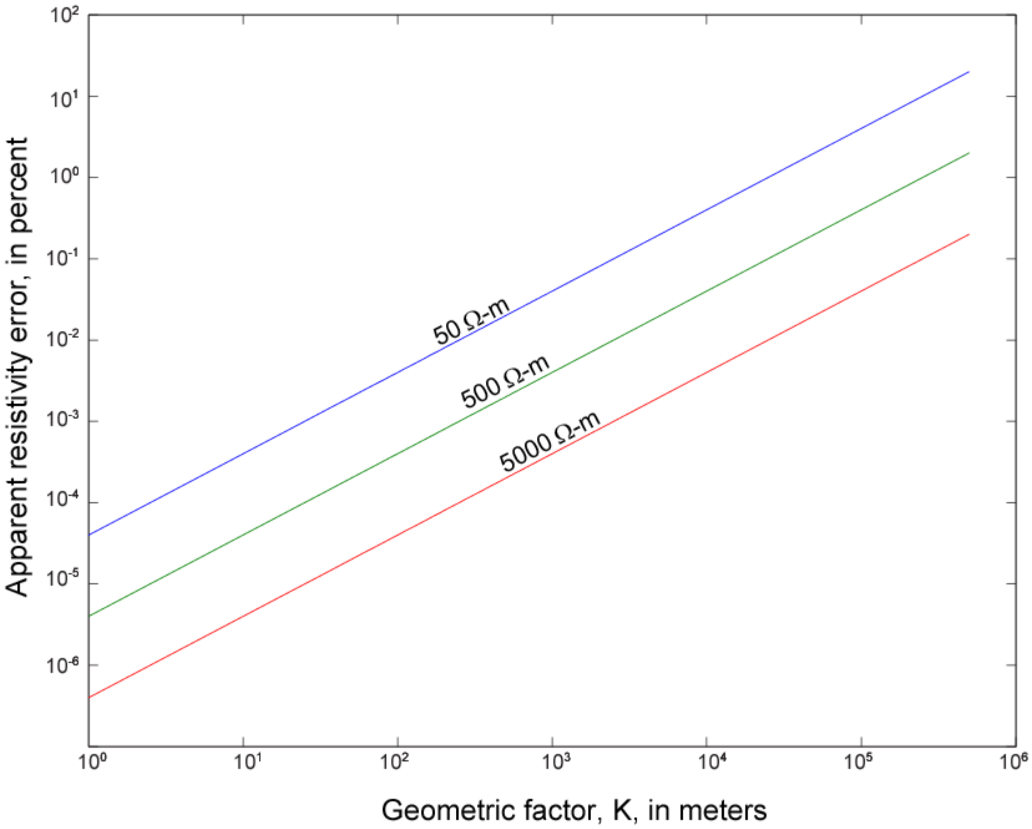

Figure 1. Apparent resistivity error, as a percent of the true apparent resistivity, as a function of geometric factor for three different values of resistivity (50, 500, and 5,000 ohm-meters (Ω-m)), assuming the voltage error is 1 microvolt and the applied current is 50 milliamperes.

2.2. Forward modeling

In designing ERI surveys, forward modeling is a powerful tool. Forward modeling codes are commonly based on finite-difference or finite-element solution of the electrical conduction equation (eqn. 1). Given a hypothetical target (fig. 2a), it is possible to simulate synthetic data for different survey geometries and noise levels for a given discretization of equation 1; these predicted data can be inverted to generate tomograms (fig. 2b). Such exercises provide insight into the resolving power of different survey geometries. In the example of figure 2, a cross-hole resistivity survey is conducted for a cross section containing a single, large (25-cm) fracture zone and no other heterogeneity. Assuming a low-noise dataset, 2 percent random normal error are added to the data. The resulting tomogram provides only a blurry and blunted image of the true resistivity distribution, and interpretation of the location and extent of the fracture zone is complicated by the limited resolution. If other heterogeneity existed in the cross section (for example, lithologic or porosity variation), or if the fracture zone were a single fracture (perhaps 2.5 mm instead of 25 cm), it might not be possible to identify the fracture at all. By considering different input models, or targets, it is also possible to gain insight into how resolution varies spatially over a tomogram.

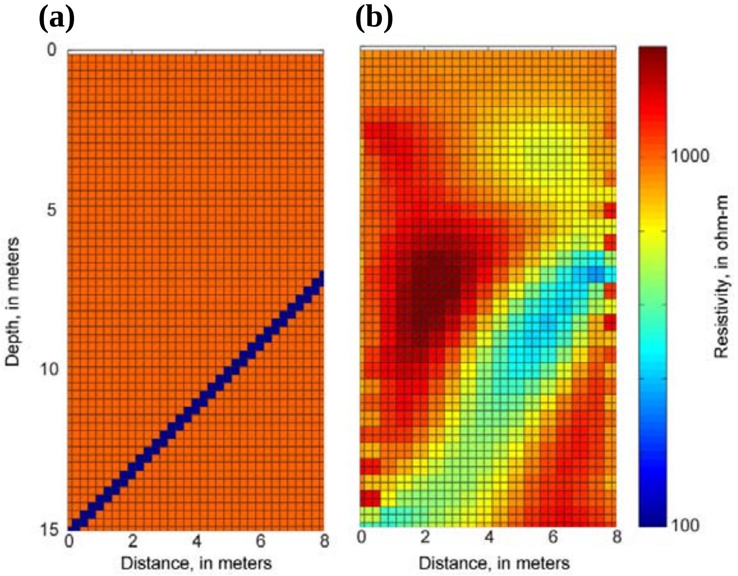

Figure 2. (a) Hypothetical electrical resistivity cross section, and (b) resulting tomogram. Because of the limited resolution of the survey, the tomogram is a blurred, blunted version of reality.

In inversion codes, forward models are used within an optimization framework to calculate predicted data for comparison with observed data. Depending on the discretization of the finite-difference grid or finite-element mesh, some quadripoles may model poorly; i.e., the inverse model would not be able to accurately match these data. Forward model accuracy thus provides another factor to consider in designing survey geometries—we can eliminate quadripoles from our geometry that will not model well and would, ultimately, be edited during inversion assuming we use the same parameterization of the numerical model. For example, we can forward model all candidate quadripoles assuming a 100-ohm-m (Ω-m) background, and calculate the apparent resistivities given the geometric factors calculated analytically above. Quadripoles that do not model well are not collected in the field. The discretization of the mesh and the location of the boundary conditions should be refined if problems exist or too many data are eliminated in this manner. As a rule of thumb, grid spacing near electrodes should be finer than one half of the electrode spacing. Grid spacing can be coarser further from electrodes. Commonly, grid spacing is increased by a factor of less than 1.5.

Once we have created the survey geometry for data collection and tested it with a forward model, we can head to the field and deploy the electrodes.

3. COLLECTION AND VERIFICATION OF FIELD DATA

Commercially available multi-node resistivity systems commonly accept input files listing which quadripoles to collect. These files are variously referred to as “sequence,” “command,” or “schedule” files. In addition to quadripoles collected for inversion, it is highly advisable to collect (1) electrode contact resistance measurements, (2) repeat measurements, and (3) reciprocal measurements, which together allow the user to determine the quality of the data both in the field and later during analysis back in the office.

3.1. Contact resistance

Resistance checks should be run on the electrodes prior to data collection to assure that contact resistances are not too large. In surface arrays, it is possible to add saltwater around electrodes to improve contact resistance, but this generally is not possible for cross-hole arrays. We generally use cutoffs of 50 kiloohms (kΩ) for borehole data or 20 kΩ for surface data. Higher values may indicate that limited current can be injected for that electrode pair. Contact resistances should be recorded manually if not automatically recorded by the instrument software. Contact resistance values can provide a basis for editing data associated with particular electrodes that are malfunctioning or in poor contact with the formation.

3.2. Stacking

It is common practice for most commercial systems to collect each quadripole several times and average the results. This procedure is referred to as “stacking.” Although collection of repeat measurements increases duration of the survey, this extra time is well worthwhile. Stacking serves to improve the signal-to-noise ratio because random noise is averaged out. In addition, the standard deviation of the repeat measurements (i.e., the stacking error) provides a means to quantify error and define data weights for inversion. Stacking errors are useful in QA/QC and form another basis for editing datasets prior to inversion. The number of repeat measurements should be recorded on field data collection forms if not recorded by the software. In some cases, the number of repeat measurements is determined by calculating the running stacking error, with more repeats collected for measurements with larger error.

3.3. Reciprocal measurements

A reciprocal measurement involves swapping current and voltage electrode pairs. In other words, electrodes *A* and *B* are swapped with electrodes *M* and *N* such that *K* remains the same. Theoretically, the reciprocal measurement should yield the same apparent resistivity as the original measurement. The standard deviation of reciprocal measurements is termed the "reciprocal error," which provides a measure of instrument error and nonlinear effects in violation of equation 1. In general, reciprocal errors are larger than stacking errors, and it is commonly thought that reciprocal measurements provide a better quantification of noise than stacking errors (Binley and others, 1995). For QA/QC, reciprocal errors may be used instead of, or in addition to, stacking errors, and are preferred for calculation of weights for inversion. Collection of reciprocal measurements tends to be slow relative to collection of stacked measurements, as the switching mechanism in the control unit must change which electrodes are being used for current and voltage pairs. To collect a reciprocal measurement involves an electronic switch between electrodes, which can take on the order of a second for modern systems, whereas a repeat measurement requires no switching and takes on the order of 50 to 500 ms depending on the pulse duration, as explained in Section 3.4.

Reciprocal measurements should not be collected immediately after their associated measurements, as polarization of the electrodes may affect the resultant measurement. Such effects generally dissipate in a few seconds. Reciprocal measurements are best collected (1) interleaved throughout the measurement sequence file, or (2) following regular data collection, depending on whether time-lapse processes are being considered, and the subsequent time lag between the "normal" and "reciprocal" measurement. For investigations of time-varying processes, the first strategy is preferred; otherwise, meaningful temporal changes would appear as error.

3.4. Pulse duration

On some instruments, the duration of the current injection can be selected by the user. Commonly, pulse duration varies from 250 ms to several seconds. Lower pulse duration results in shorter data acquisition time. Pulses on the order of 250 ms may be acceptable in conductive, low-clay media; in the presence of clays and induced polarization, however, longer durations may be required to achieve equilibrium voltages. The length of the pulse duration can be varied, and surveys repeated, to determine the minimum duration necessary to achieve good data.

3.5. Notes on field conditions

Notes on the location of electrical lines, radio transmission towers, known metallic objects, topography, and weather should be collected at each field site, as should decisions about the QA/QC procedures above. The battery voltage should be checked and recorded, as should the position of the electrodes, how their position was determined (tape, GPS, etc.), and how the electrodes were deployed and (or) built. Information on well construction (casing length, total depth, borehole integrity, presence of monitoring equipment, etc.) should be known prior to installing cables and injecting current. Some commercially available systems provide a test resistor to verify the correct operation of the instrument. Results of this test, if performed, should be recorded.

3.6. Checks for outlier data

In cases where time-varying processes are not expected to occur, replicate datasets should be collected to quantify error in measurements, and to check for poorly performing quadripoles, which may be removed. Apparent resistivities should match within a few percent, if not better. In the case of time-lapse imaging, collecting multiple background datasets can be useful for determining systematic errors and is generally worth the time, as the most time-consuming part of resistivity data collection usually is deploying the electrode strings. Note that the resistance measurements can be both positive and negative (as geometric factors can be positive or negative), but apparent resistivities should be positive in most circumstances. In cases of extreme layering or certain electrode arrangements, negative apparent resistivities may result. For this reason, it is important to collect signed voltages in the field.

4. DATA INVERSION

Once the data are collected, the resistance data are inverted to make electrical resistivity images. A variety of public domain and commercially available inversion codes are in use within the geophysical community. Most codes follow similar inversion approaches, which are based on quasi-Newton algorithms. Depending on selection of modeling and inversion parameters, these codes can be made to produce similar results; default values differ greatly, however, and it is not always clear how parameters are used within the inversion. Selection of many of these parameters can be somewhat subjective, and guided by the geophysicists' intuition or prior knowledge of the site geology or the nature of the targets. For example, in a layered system, one might choose to apply anisotropic smoothing, which will result in a tomogram that has a layered character. For results to be reproducible, it is critical to (1) report all parameter selections and default values; (2) document the algorithm used by the software; and (3) archive a copy of the software code or executable. Justifications of parameter choices should also be documented.

We note that, in general, a number of issues complicate interpreting images from electrical resistivity inversion: there is not enough information to uniquely determine all the local bulk resistivity parameter values because a finite number of resistance measurements are collected; data errors create ill-conditioning; and calculating the true distribution of resistivity in the subsurface is a highly non-linear problem because the current paths through the medium are dependent on the resistivity structure, as has been described elsewhere (Day-Lewis and others., 2005; Singha and Moysey, 2006). Most tomographic problems in geophysics are solved with an excess number of model parameters and use regularization to create a mathematically stable solution (e.g., Constable and others, 1987). Due to these issues, this problem is solved using iterative inversion (Tripp and others, 1984; Daily and Owen, 1991). The solution to the inverse problem is a map of electrical resistivity values and is usually based on non-linear least-squares minimization of a two-part objective function. The first part is the misfit between the predicted and measured resistance values. This part of the objective function minimizes the discrepancy between field resistance data and the computed resistances based on Poisson's Equation (eqn. 1).

The second part is the regularization term, which minimizes the roughness of the electrical resistivity field and allows for well-posedness of the inverse problem. For resistivity inversion, this objective function, *F*, is given by

$$F = \left(\mathbf{d} - g\left(\hat{\mathbf{m}}\right)\right)^T \mathbf{C}_D^{-1} \left(\mathbf{d} - g\left(\hat{\mathbf{m}}\right)\right) + \alpha\, \hat{\mathbf{m}}^T\, \mathbf{D}^T \mathbf{D}\, \hat{\mathbf{m}} \tag{4}$$

where

$\mathbf{d}$ is the vector of electrical resistance measurements;

$g(\cdot)$ is the forward model for electric potential (eqn. 1);

$\hat{\mathbf{m}}$ is the vector of parameter estimates, (log electrical conductivity or resistivity);

$\mathbf{C}_D$ is the covariance matrix of measurement errors;

α is the regularization parameter that determines the importance given to the smooth appearance of the electrical conductivity field relative to the misfit between calculated and observed resistances**;** a small α will minimize the residual error between measured and modeled resistances but may not converge to a unique solution, whereas a large α will identify an overly smooth electrical conductivity field that may not fit the measured field data (resistances) well (see, for example Tikhonov and Arsenin, 1977);

and

$\mathbf{D}$ is the model-weighting regularization matrix, which can be defined by either a discretized second-derivative filter or the covariance of the model parameters (Tarantola, 1987; Gouveia and Scales, 1997; Kitanidis, 1997; Vasco and others, 1997; Day-Lewis and others, 2003).

The model parameters are updated in an iterative fashion by repeated solution of a linear system of equations for $\Delta\hat{\mathbf{m}}$ at successive iterations. Such an approach results in the regularization changing throughout the iterative process. This issue makes it difficult to map the effect of regularization throughout the inversion process, and consequently impairs quantitative inference from the images. The update appears like the following:

$$\left[\mathbf{J}^T \mathbf{C}_D^{-1} \mathbf{J} \;\; + \alpha\, \mathbf{D}^T \mathbf{D}\right] \Delta\hat{\mathbf{m}} = \mathbf{J}^T \mathbf{C}_D^{-1} \left(\mathbf{d} - g\left(\hat{\mathbf{m}}_{k-1}\right)\right) - \alpha\, \mathbf{D}^T \mathbf{D}\, \hat{\mathbf{m}}_{k-1} \tag{5a}$$

$$\hat{\mathbf{m}}_k = \hat{\mathbf{m}}_{k-1} + \Delta\hat{\mathbf{m}} \tag{5b}$$

where

$\mathbf{J}$ is the Jacobian matrix, with elements $J_{ij} = \partial\hat{d}_i \big/ \partial\hat{m}_j$;

$\hat{d}_i$ is the calculated value of measurement *i*;

$\hat{\mathbf{m}}_k$ is the vector of parameter estimates after updating in iteration *k*; and

$\Delta\hat{\mathbf{m}}$ is the vector of parameter updates for iteration *k*.

Although tomographic inversion with regularization is useful for imaging large-scale (low spatial frequency) structures, it yields poor results when attempting to infer quantitative values from the recovered images (e.g., Binley et al., 2002; Singha and Gorelick, 2005; Day-Lewis et al., 2007). This effect is often caused by over-regularization of the solution during inversion, as well as over-parameterization of the inverse problem. The following issues are important considerations for the electrical inverse problem:

4.1. Selection of inversion parameters to prevent overfitting/underfitting of data

Data should be weighted by their measurement (reciprocal or stacking) errors, as stressed above, to prevent overfitting or underfitting of the data. In other words, the inversions will match the data to within the expected measurement errors, given errors seen in the field. Occam inversion refers to an approach that seeks to objectively set the tradeoff between the data match and the complexity (roughness) of the inverted resistivity tomograms (Constable and others, 1987). Some software packages leave it to the user to decide when the inversion has converged, placing the burden of balancing the tradeoff between the model and data misfit on the scientists subjective judgment. All selections of inversion parameters should be recorded and reported.

4.2. Definition of data misfit

In equation 4, the data misfit is based on an L2 norm, i.e., as the sum of weighted, squared differences between predicted and observed values. The L2 norm is highly sensitive to outlier data, hence the need to carefully edit datasets and remove data corresponding to electrodes with poor electrical contact or faulty channels. Many inversion packages also support minimization of the L1 data misfit, which is commonly referred to as robust inversion. The L1 norm is based on absolute differences instead of squared differences, and is therefore less sensitive to outliers (Claerbout and Muir, 1973). We note that the L1 norm also can be used in defining the model misfit (i.e., roughness in the case where **D** is a second derivative filter), which is appropriate if sharp boundaries are expected. It is important not to confuse the use of L1 for data misfit with the L1 for model misfit.

4.3. Quantification of inversion quality

Several approaches are commonly used to gain insight into the reliability of tomograms. For small inverse problems, it is possible to calculate the model resolution matrix [e.g., Menke, 1984; Ramirez and others, 1993; Alumbaugh and Newman, 2000; Day-Lewis and Lane, 2004] and present the diagonals, rows, and columns of these matrices as cross sectional images. Conceptually, the model resolution matrix is the lens or filter through which the inversion *sees* the study region. For a linear inverse problem,

$$\hat{\mathbf{m}} = \left[\mathbf{J}^T \mathbf{C}_D^{-1} \mathbf{J} \; + \alpha \, \mathbf{D}^T \mathbf{D} \right]^{-1} \mathbf{J}^T \mathbf{C}_D^{-1} \, \mathbf{d} \approx \left[\mathbf{J}^T \mathbf{C}_D^{-1} \mathbf{J} \; + \alpha \, \mathbf{D}^T \mathbf{D} \right]^{-1} \mathbf{J}^T \mathbf{C}_D^{-1} \, \mathbf{J} \, \mathbf{m}_{true} \,, \tag{6}$$

the model resolution matrix, **R**, is defined as

$$\mathbf{R} = \left[\mathbf{J}^T \mathbf{C}_D^{-1} \mathbf{J} \; + \alpha \, \mathbf{D}^T \mathbf{D} \right]^{-1} \mathbf{J}^T \mathbf{C}_D^{-1} \, \mathbf{J} \,, \tag{7}$$

and thus,

$$\hat{\mathbf{m}} = \mathbf{R} \, \mathbf{m}_{true} \,. \tag{8}$$

For linear problems, where **J** is independent of $\mathbf{m}_{true}$, **R** can be calculated prior to data collection. Given a model of measurement errors, the model resolution matrix can be calculated using equation 7 and used as a tool to assess and refine hypothetical survey designs and regularization criteria. In interpreting inversion results, **R** is useful for identifying likely inversion artifacts (Day-Lewis and others, 2002). The model resolution matrix quantifies the spatial averaging inherent to tomography; hence it gives insight into which regions of a tomogram are well resolved versus poorly resolved. This information is valuable if tomograms are to be converted to quantitative estimates of porosity, concentration, or other hydrologic parameters.

Calculation of resolution matrices remains computationally intensive or prohibitive for many problems; hence few commercially available software packages support calculation of **R**, and it is instead more common to look at an inverse problem's sensitivity matrix:

$$\mathbf{S} = diag\left(\mathbf{J}^{T}\,\mathbf{J}\right), \tag{9}$$

where **S** is the sensitivity matrix and *diag*($\cdot$) indicates the diagonal elements of a matrix. The sensitivity matrix can be used to gain semi-quantitative insight into how resolution varies spatially over a tomogram. Pixels with high values of sensitivity are relatively well informed by the measured data, whereas pixels with low values of sensitivity are poorly informed. It is important to note that, in contrast to **R**, **S** does not account for the effects of regularization criteria (as contained in **D**) or measurement error (as contained in $\mathbf{C}_D$); rather, **S** is based only on the survey geometry and measurement sensitivity.

4.4. Checks on inversion results

Tomographic inversion results are strongly affected by selected inversion parameters and regularization criteria, especially in the presence of large measurement errors. It is instructive, therefore, to run multiple inversions in order to gain insight into the effects of different software settings. Rarely are default inversion settings appropriate. The process for selecting inversion settings should be guided by whatever prior information the geophysicist has at his or her disposal. Such information could include past geophysical results, geologic maps, and drillers logs. If inverted resistivity cross sections are inconsistent with such prior information (e.g., values from electromagnetic logs), this could indicate that settings are sub-optimal or that assumptions (e.g., 2-D heterogeneity) are violated. Table 1 lists some common problems and their associated symptoms and solutions.

Table 1. Common problems with inversion settings, and the associated symptoms and solutions.

Symptom	Possible problems	Solution
Minimum/maximum estimated resistivity too low/high compared to expected values	The inversion may be overfitting the data	• Stop inversion at an earlier iteration or increase the assumed measurement error
	Non-random outlier data may be present	• Check the dataset for outliers and edit • Try the L1 norm for data misfit
Tomogram is speckly or looks like a checkerboard	The inversion may be overfitting the data	• Stop inversion at an earlier iteration or increase the assumed measurement error in Occam inversion
	Non-random outlier data may be present	• Check the dataset for outliers and edit • Try the L1 norm for data misfit
The inversion can not match the data to within the reciprocal error	The optimization algorithm may be caught in a local minimum	• Change optimization tolerances • Increase number of iterations • Update the Jacobian more frequently • Change the starting model
	The finite-difference or finite-element grid may be too coarse	• Refine the grid or mesh
	The inversion grid may be too coarse	• Increase the number of inversion parameters
	Non-random outlier data may be present	• Check the dataset for outliers and edit • Try the L1 norm for data misfit
The tomogram does not look like expected geology	Regularization criteria may be smoothing/blunting the tomogram too much	• Try robust model misfit instead of L2 model misfit • Use anisotropic regularization • Try different regularization criteria
	Resistivity may not correlate with lithology	• Another geophysical technique may be needed
Two (or more) tomograms that share a borehole appear inconsistent at the borehole	Electrical anisotropy	• Use an inversion package with a forward model that allows for resistivity anisotropy
	Outlier data are present in at least one dataset	• Check the dataset for outliers and edit • Try the L1 norm for data misfit
Tomograms show vertical streaking, or high or low resistivity patches only at boreholes	Resolution may vary greatly from the sides to the middle of the tomogram	• Create synthetic or hypothetical forward models of the experiment to evaluate resolution and likely artifacts • Examine plots of the inversion's sensitivity or resolution matrix

5. CORINNA FIELD EXPERIMENTS

Electrical resistivity data were collected in July 2007 to image fractured rocks at the Eastern Woolen Mill Superfund site, Corinna, Maine. The goals of this work were to (1) demonstrate best practices, and (2) provide site-specific insight into heterogeneity and help evaluate the utility of ERI in the fractured bedrock at the site. The electrical resistivity tomography (ERT) survey was not expected to image individual discrete fractures because fracture apertures are commonly on the order of microns to millimeters, whereas the resolution or ERT tomograms is on the order of tens of centimeters to meters (e.g., fig. 1). Larger fracture zones, however, could manifest resistivity anomalies.

Data were collected for four cross sections connecting four wells: BM 32, BM 34, BM 37, and BM 38 (fig. 3). Based on USEPA's prioritization of cross sections for electrical imaging, cross-hole resistance data were collected according to the following order of well pairs: (1) BM-34/BM-37, (2) BM-34/BM-38, (3) BM-37/BM-38, and (4) BM-32/BM-34. The wells were 6-in. (15-cm) open holes over the intervals where electrodes were placed, with steel casing above this zone.

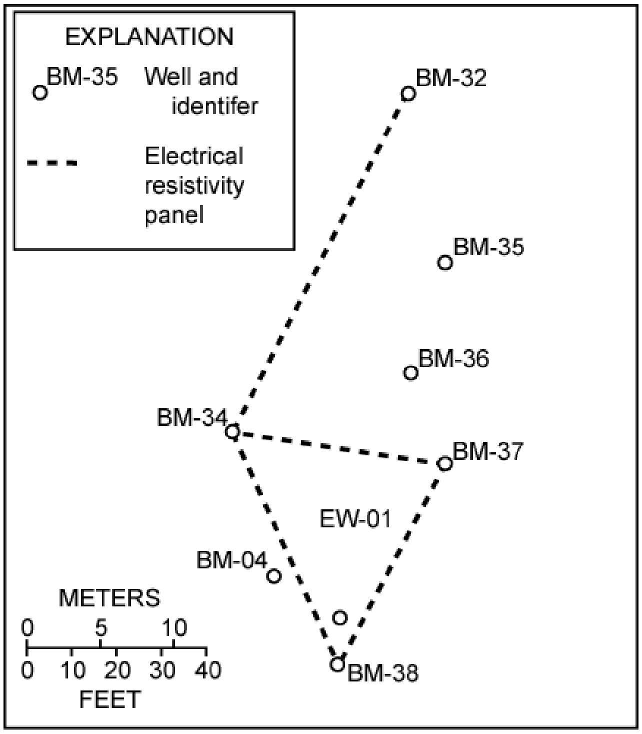

Figure 3. Layout of electrical resistivity panels collected for this investigation at the Eastland Woolen Mill Superfund site, Corinna, Maine.

5.1. Data collection

We used Pennsylvania State University's 10-channel IRIS Syscal Pro[1] (http://www.iris-instruments.com/Product/Brochure/syscal.html) (fig. 4) to collect data for a mixed survey geometry combining in-well and cross-well dipoles. The Syscal Pro measures voltages between electrodes resulting from an applied current, which is set by the user in terms of the applied voltage. The instrument is also capable of induced polarization and spontaneous potential measurements, but the discussion of these capabilities is outside the scope of this report.

The downhole cables had 24 stainless-steel electrodes each, at 1.25-m spacing. Cables were suspended in wells such that the top-most electrodes were aligned at the same elevation. To cover the entire vertical extent of wells, cables were set over three different vertical intervals. For each vertical interval of a cross-hole plane, we collected: (1) 625 cross-well quadripole data and 625 reciprocal data; and (2) 118 in-well Wenner data with a-spacings of 1 and 2; this procedure was applied also for 3-D data collection, which simply comprised multiple 2-D cross-sectional datasets from three vertical intervals (we note, however, that there is nothing inherently 2-D about flow processes; current flow is always in 3-D in the subsurface). Data were collected for one 2-D cross section at a time. A summary of the data collection is given in table 2, and the 'sequence files' used for data collection (e.g., file 'DipDip3d.txt') are included in appendix 1. A sequence file comprises a list of instructions for the resistivity instrument about which quadripoles to collect. Additional settings (e.g., pulse duration, applied voltage, etc.) were set in the field and are reported in the standard USGS data collection forms (fig. 5). Completed field notes are provided as appendix 2. Note that we collected the same dataset with multiple instrument configurations to illustrate how user selections affect data quality, e.g., the choice of applied voltage, the pulse duration, etc. These settings are all reported in appendix 2.

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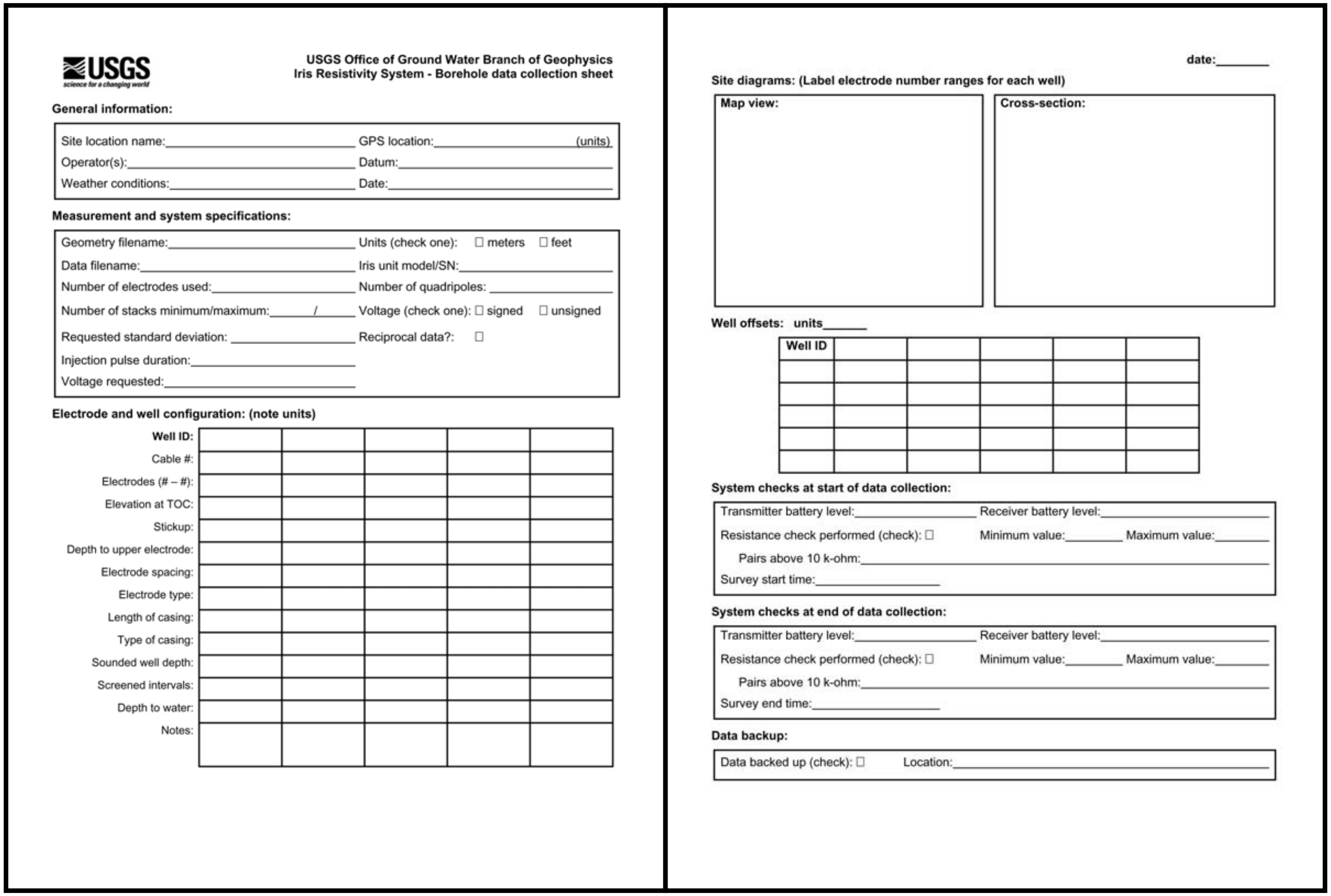
[1] Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Figure 4. The IRIS Syscal Pro 10-channel resistivity instrument.

Table 2. Summary of data collected at the Eastland Woolen Mills Superfund Site, Corinna, Maine

Data Filename in field	Wells in survey	Depth of top electrode (meters)	Number. of measurements	Storage starting on block number	Ending Block	Date	Start time	End time	Comments
DipDip3d	(34, 37, 38)	15.0	1639	0	1639	7/9/07	12:35		
DipDip3d_recip	(34, 37, 38)	15.0	1639	1639	3278	7/9/07	13:35	15:45	
DipDip3d	(34, 37, 38)	22.5	1639	3278	4917	7/9/07	16:15		
DipDip3d_recip	(34, 37, 38)	22.5	1639	4917	6556	7/9/07	17:07	19:07	
DipDip3d	(34, 37, 38)	30.0	1639	6556	7101	7/10/07	8:40		
DipDip3d	(34, 37, 38)	30.0	1639	7102	7648	7/10/07	9:00		
Fred3d.txt	(34, 37, 38)	30.0	1639	0	587	7/10/07	10:23		
DipDip2d	(37,38)	29.5	625	588		7/10/07	11:29		
DipDip3d_recip	(34, 37, 38)	30.0	1638	681	2319	7/10/07	11:55	13:50	
DipDip3d	(34, 37, 38)	30.0	1638	2320	3958	7/10/07	14:02	15:54	
Wenmer3d	(34, 37, 38)	30.0	118	3959	4077	7/10/07	16:10		
Wenmer3d_recip	(34, 37, 38)	30.0	118	4077	4194	7/10/07	16:20		
Wenmer3d	(34, 37, 38)	22.5	118	4195	4312	7/10/07	16:51		
Wenmer3d_recip	(34, 37, 38)	22.5	118	4313	4430	7/10/07	17:03	17:12	
Wenmer3d	(34, 37, 38)	15.0	118	4431	4548	7/10/07	17:30	17:44	
Wenmer3d_recip	(34, 37, 38)	15.0	118	4549	4666	7/10/07	17:49	17:59	
DipDip2d	(34, 32)	15.0	625	4667	5291	7/11/07	8:26	8:46	
DipDip2d-recip	(34, 32)	15.0	625	5292	5916	7/11/07	8:48	9:31	
DipDip2d	(34, 32)	22.5	625	5917	6541	7/11/07	10:35	10:55	
DipDip2d-recip	(34, 32)	22.5	625	6542	7166	7/11/07			
DipDip2d-recip	(34, 32)	30.0	625	7167	7791	7/11/07	11:55	12:45	
DipDip2d	(34, 32)	30.0	625	7792	8416	7/11/07	13:00	13:45	Single channel collection- due to heat
DipDip2d	(34, 32)	30.0	625	8417	9041	7/11/07	14:00	15:15	Redo with 2X pulse duration (1s), single channel collection
DipDip2d-recip	(34, 32)	30.0	625	9042	9666	7/11/07	15:25	16:35	Redo with 2X pulse duration (1s), single channel collection
DipDip2d	(34, 32)	30.0	625	9667	10291	7/12/07	8:27	9:03	Redo with ½ line pulse duration (250ms), 1 channel collection
DipDip2d-recip	(34, 32)	30.0	625	10292	10918	7/12/07	9:06	9:40	Redo with ½ line pulse duration (250ms), 1 channel collection
DipDip2d	(34, 32)	30.0	625	10917	11541	7/12/07	9:50	10:30	Redo with 500 ms duration and 800 mV power
DipDip2d-recip	(34, 32)	30.0	625	11542	12166	7/12/07	10:40	11:30	Redo with 500 ms duration and 800 mV power
DipDip2d	(34, 32)	22.5	625	12167	12791	7/12/07	12:34	12:58	With 10 channels and air conditioning (AC)
DipDip2d-recip	(34, 32)	22.5	625	12792	13416	7/12/07	13:00	13:51	With 10 channels and AC
DipDip2d-recip	(34, 32)	15.0	625	13417	14041	7/12/07		14:53	With 10 channels and AC
DipDip2d	(34, 32)	15.0	625	14042	14666	7/12/07	14:55	15:09	With 10 channels and AC



USGS science for a changing world

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name:____________________ GPS location:________________ (units)
Operator(s):____________________ Datum:____________________
Weather conditions:____________________ Date:____________________

Measurement and system specifications:

Geometry filename:____________________ Units (check one): ☐ meters ☐ feet
Data filename:____________________ Iris unit model/SN:____________________
Number of electrodes used:________________ Number of quadripoles: ________________
Number of stacks minimum/maximum:______/______ Voltage (check one): ☐ signed ☐ unsigned
Requested standard deviation: ________________ Reciprocal data?: ☐
Injection pulse duration:____________________
Voltage requested:____________________

Electrode and well configuration: (note units)

Well ID:					
Cable #:					
Electrodes (# – #):					
Elevation at TOC:					
Stickup:					
Depth to upper electrode:					
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:					

date:________

Site diagrams: (Label electrode number ranges for each well)

Map view:

Cross-section:

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level:________________ Receiver battery level:____________________
Resistance check performed (check): ☐ Minimum value:________ Maximum value:________
Pairs above 10 k-ohm:____
Survey start time:________________

System checks at end of data collection:

Transmitter battery level:________________ Receiver battery level:____________________
Resistance check performed (check): ☐ Minimum value:________ Maximum value:________
Pairs above 10 k-ohm:____
Survey end time:________________

Data backup:

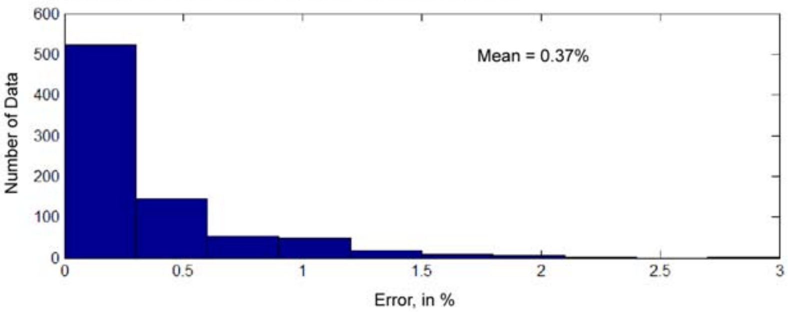
Data backed up (check): ☐ Location:____

Figure 5. USGS IRIS Syscal Pro data-collection form for cross-hole ERT.

5.2 Data quality

Data quality is partly a function of instrument output current, which depends on the equipment's maximum driving voltage, electrode contact resistance, resistivity of the medium, and distance between electrodes. As discussed earlier, errors are quantified by standard errors from repeat measurements, and (or) reciprocal measurements. It is common to eliminate outlier data prior to inversion; these bad data result from a number of factors, including (1) high geometric factors, which result in a poor signal-to-noise ratio; (2) high contact resistance, which occurs when electrodes are in poor contact with the formation; and (3) insufficient (low relative to what is needed) current injection, especially in highly resistive media. Here, for our base-case inversions, we eliminated data with standard errors larger than 3 percent, reciprocal errors larger than 3 percent, or applied current less than 250 mA. Electrodes with contact resistance higher than 10 kΩ were noted in the field forms (appendix 2), and data associated with these electrodes were eliminated during editing. This editing was performed outside of inversion software. In general, the data collected at the Eastland Woolen Mills Superfund Site show large errors. To eliminate data with more than 3 percent stacking and (or) reciprocal error, it was necessary to remove about 40 percent of the raw data. Other criteria (e.g., geometric factor) could be used to define cutoffs to further edit the dataset; however, elimination of 40 percent of the original data was judged to be severe and further editing extreme. Histograms of errors for a representative, edited dataset for the BM-34/BM-38 cross section are shown in figure 6. The reciprocal error for this dataset is, on average, about twice the stacking error. As discussed in section 3.3, reciprocal measurements are commonly considered to provide more meaningful quantification of errors, incorporating instrument error, error arising from nearby anthropogenic current sources (cathode protection systems), natural electrical storms, and (or) physical effects in violation of equation 1.

(a) Standard Errors from Repeat Measurements



(b) Reciprocal Measurements

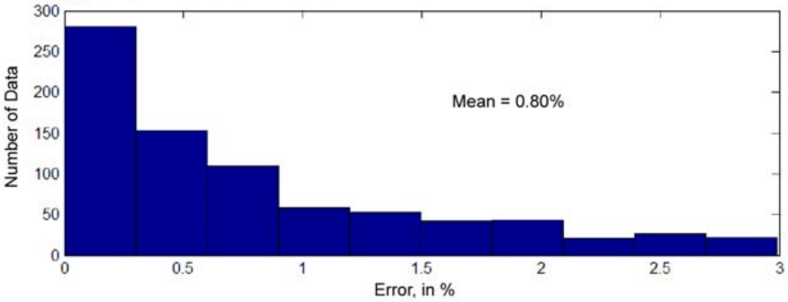


Figure 6. Standard (a) and reciprocal (b) errors for the BM-34/BM-38 cross section.

5.3 Inversions

Inversions were performed using two popular commercially available software packages for comparison: AGI EarthImager and Res2DInv. For the base-case inversion, we used measured resistances as data (note that it is also possible to use apparent resistivity as data), and used reciprocal errors to determine data weights. For the regularization criteria, we applied a horizontal-to-vertical smoothing of 2:1, to promote smoothness in the horizontal direction. We stress that for many ERT problems, the choices of regularization and data weighting can strongly affect results, and it is critical to experiment with different approaches to help distinguish artifacts from geologic features. Features common to a suite of tomograms inverted from the same dataset should inspire some degree of confidence for interpretation whereas features that result only for a specific inversion setting or regularization are more likely to be artifacts. To demonstrate this concept, figures 7-9 show a series of tomograms for the BM-34/BM-38 cross section, generated from the same dataset with different inversion settings for (1) regularization criteria, smoothness versus damping (smallness) (fig. 7); (2) software package, AGI Earth Imager and Res2DInv, with default settings (fig. 8); and (3) different convergence criteria for data matching (fig. 9).

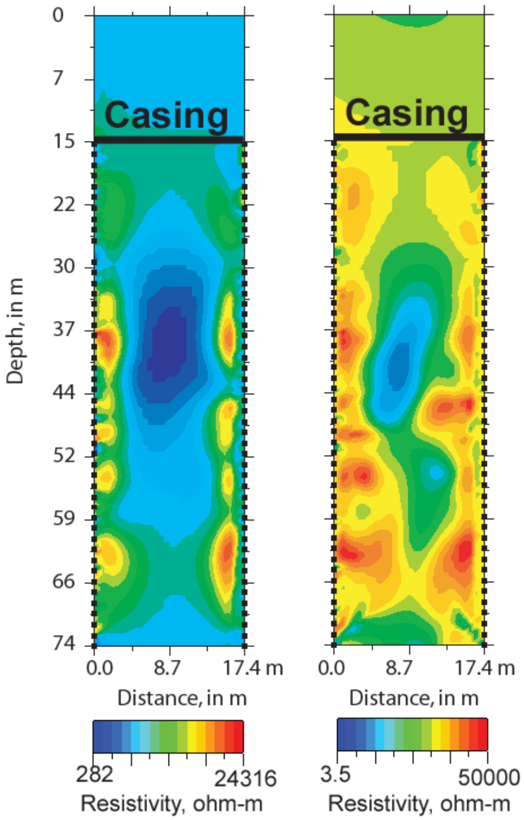


Figure 7. Effect of regularization criteria for tomograms of the BM-34/BM-38 cross section. In each tomogram, borehole BM-34 is on the left and borehole BM-38 is on the right. (a) Smoothness-based inversion, and (b) smallness-based inversion. Both tomograms have a 30 percent root-mean-squared error match to the data.

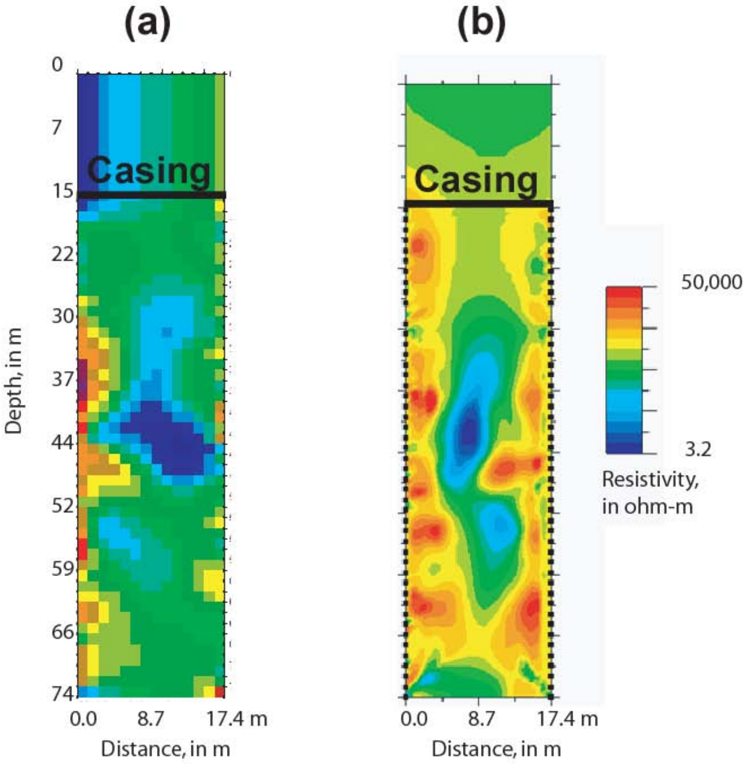


Figure 8. Effect of using different inversion packages with default settings for tomograms of the BM-34/BM-38 cross section: (a) Res2DInv and (b) EarthImager. In each tomogram, borehole BM-34 is on the left and borehole BM-38 is on the right.

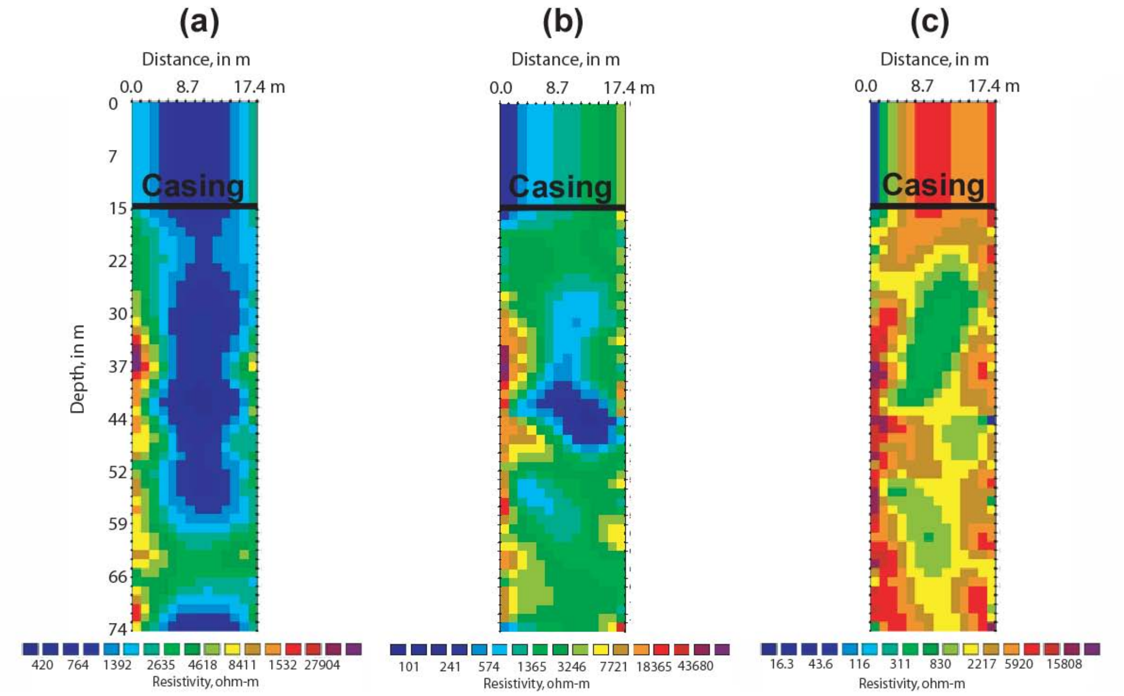


Figure 9. Effect of convergence criterion for tomograms of the BM-34/BM-38 cross section: (a) 20.4 percent, (b) 12.3 percent, and (c) 8.4 percent root-mean-squared match to data. In each tomogram, borehole BM-34 is on the left and borehole BM-38 is on the right.

To facilitate comparison of different cross sections, it is strongly recommended to select inversion settings in a consistent and well documented manner. For example, to enable interpretation and comparison of data at Corinna, we first focus on a single cross section and apply different settings (figs. 7-9), and establish a strategy to apply consistently to the remaining cross sections. Because the dataset shows large error, as discussed in Section 5.2, we choose to minimize the L1 norm between the predicted and observed data for the objective function in the inversion. We applied a 2:1 smoothing in the horizontal:vertical direction, used resistances as data for the inversion, and used a L2 measure of the model misfit. Additional damping was required to stabilize the inversion results for the BM-34/BM-32 dataset, for which the well offset was large. A complete list of inversion settings are reported in “ivp” files output from Res2DInv in appendix 3. Tomograms and sensitivity plots generated with Res2DInv for the cross sections BM-34/BM-38, BM-34/BM-37, BM-37/BM-38, BM-34/BM-32 are shown in figures 10-13 and 14-17, respectively. With the exception of the BM-34/BM-32 cross section, the tomograms are annotated with interpreted transmissive zones identified in pumped-flow flowmeter logs (PF), ambient-flow flowmeter logs (AF), temperature logs (T), and fluid resistance logs (R). Where fluid-filled fractures are present, we expect a possible decrease in the resistivity relative to the unfractured rock. The BM-34/BM-32 tomogram has a larger interwell spacing and resulted in a particularly poor comparison to the hydraulic features identified in wells using flowmeter or borehole geophysics. In general, the tomograms show large variations in resistivity, in excess of three orders of magnitude. Sensitivity (calculated according to equation 9 and then normalized) varies over the tomograms, with the highest sensitivity near boreholes where the electrodes are located. Sensitivity tends to be high in regions of lower resistivity (higher conductivity), because current focuses into more conductive features.

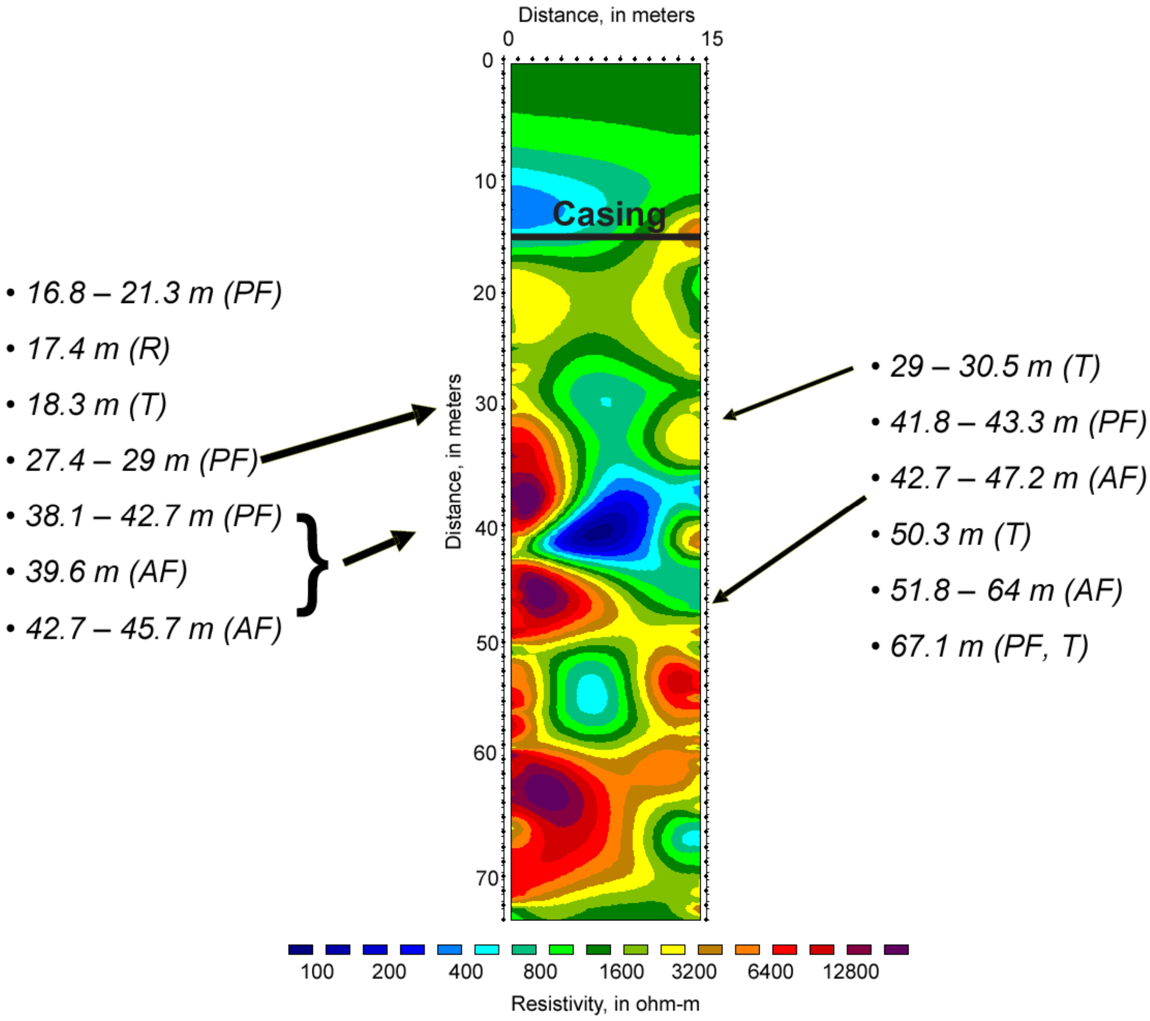
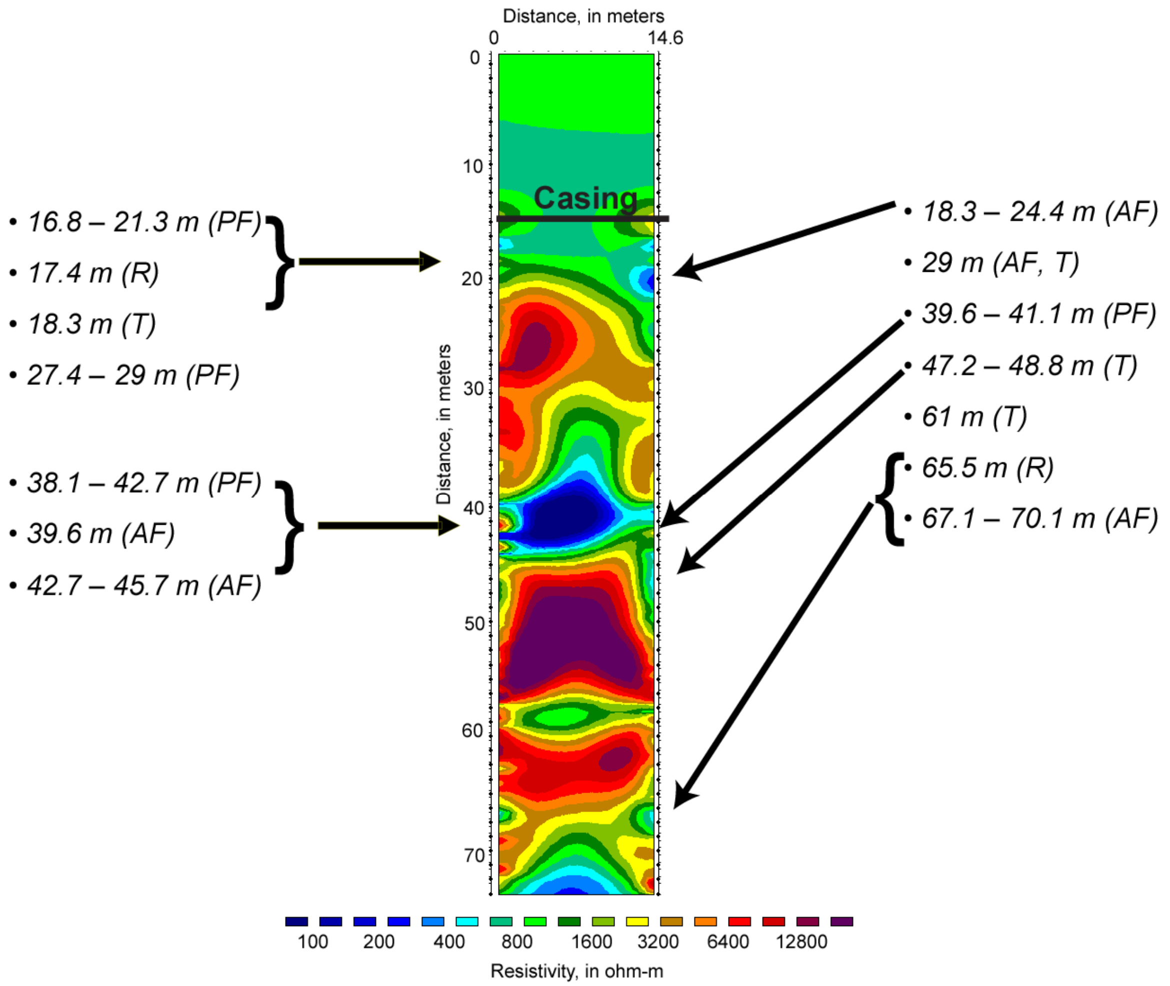


Figure 10. Resistivity tomogram for the BM-34/BM-38 cross section and features identified in borehole logs (PF, pumped flow; AF, ambient flow; T, temperature; R,resistance). On the tomogram, borehole BM-34 is on the left and borehole BM-38 is on the right.

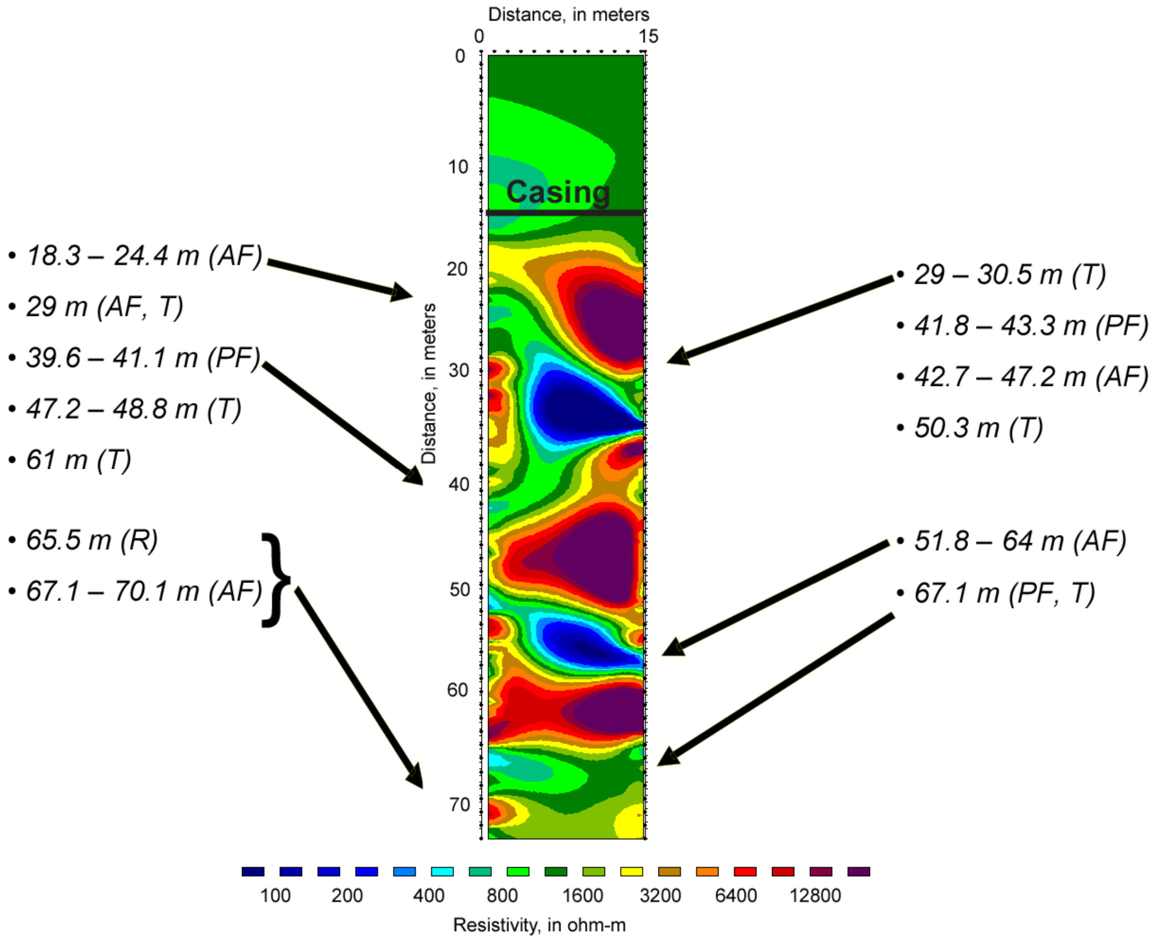


- *16.8 – 21.3 m (PF)*
- *17.4 m (R)*
- *18.3 m (T)*
- *27.4 – 29 m (PF)*

- *38.1 – 42.7 m (PF)*
- *39.6 m (AF)*
- *42.7 – 45.7 m (AF)*

- *18.3 – 24.4 m (AF)*
- *29 m (AF, T)*
- *39.6 – 41.1 m (PF)*
- *47.2 – 48.8 m (T)*
- *61 m (T)*
- *65.5 m (R)*
- *67.1 – 70.1 m (AF)*

Figure 11. Resistivity tomogram for the BM-34/BM-37 cross section and features identified in borehole logs (PF, pumped flow; AF, ambient flow; T, temperature; R, resistance). On the tomogram, borehole BM-34 is on the left and borehole BM-37 is on the right.



- 18.3 – 24.4 m (AF)
- 29 m (AF, T)
- 39.6 – 41.1 m (PF)
- 47.2 – 48.8 m (T)
- 61 m (T)

- 65.5 m (R)
- 67.1 – 70.1 m (AF)

- 29 – 30.5 m (T)
- 41.8 – 43.3 m (PF)
- 42.7 – 47.2 m (AF)
- 50.3 m (T)

- 51.8 – 64 m (AF)
- 67.1 m (PF, T)

Figure 12. Resistivity tomogram for the BM-37/BM-38 cross section and features identified in borehole logs (PF, pumped flow; AF, ambient flow; T, temperature; R, resistance). On the tomogram, borehole BM-37 is on the left and borehole BM-38 is on the right.

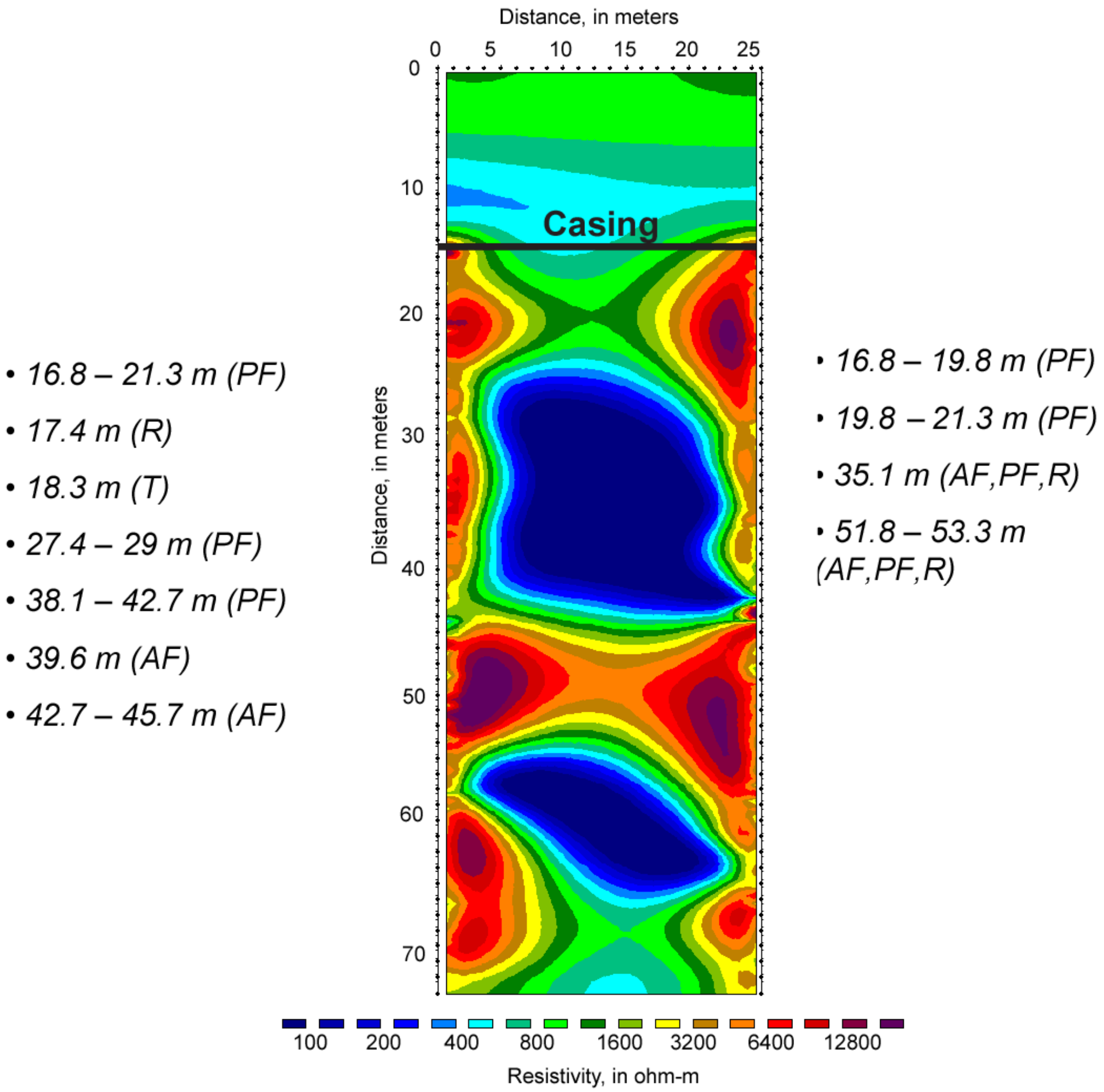


Figure 13. Resistivity tomogram for the BM-34/BM-32 cross section and features identified in borehole logs (PF, pumped flow; AF, ambient flow; T, temperature; R,resistance). On the tomogram, borehole BM-34 is on the left and borehole BM-32 is on the right.

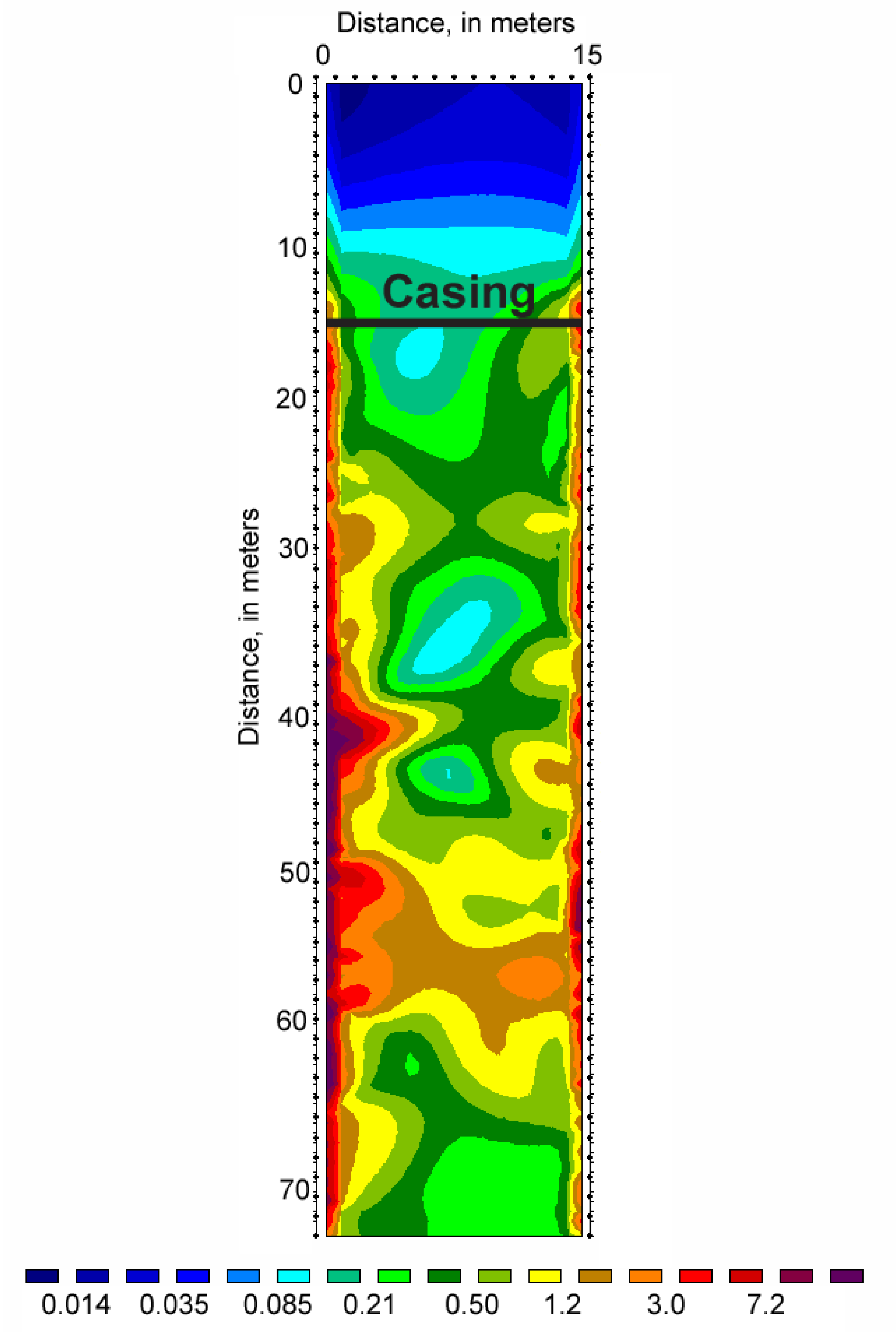


Figure 14. Relative sensitivity of the resistivity tomogram for the BM-34/BM-38 cross section. On the tomogram, borehole BM-34 is on the left and borehole BM-38 is on the right.

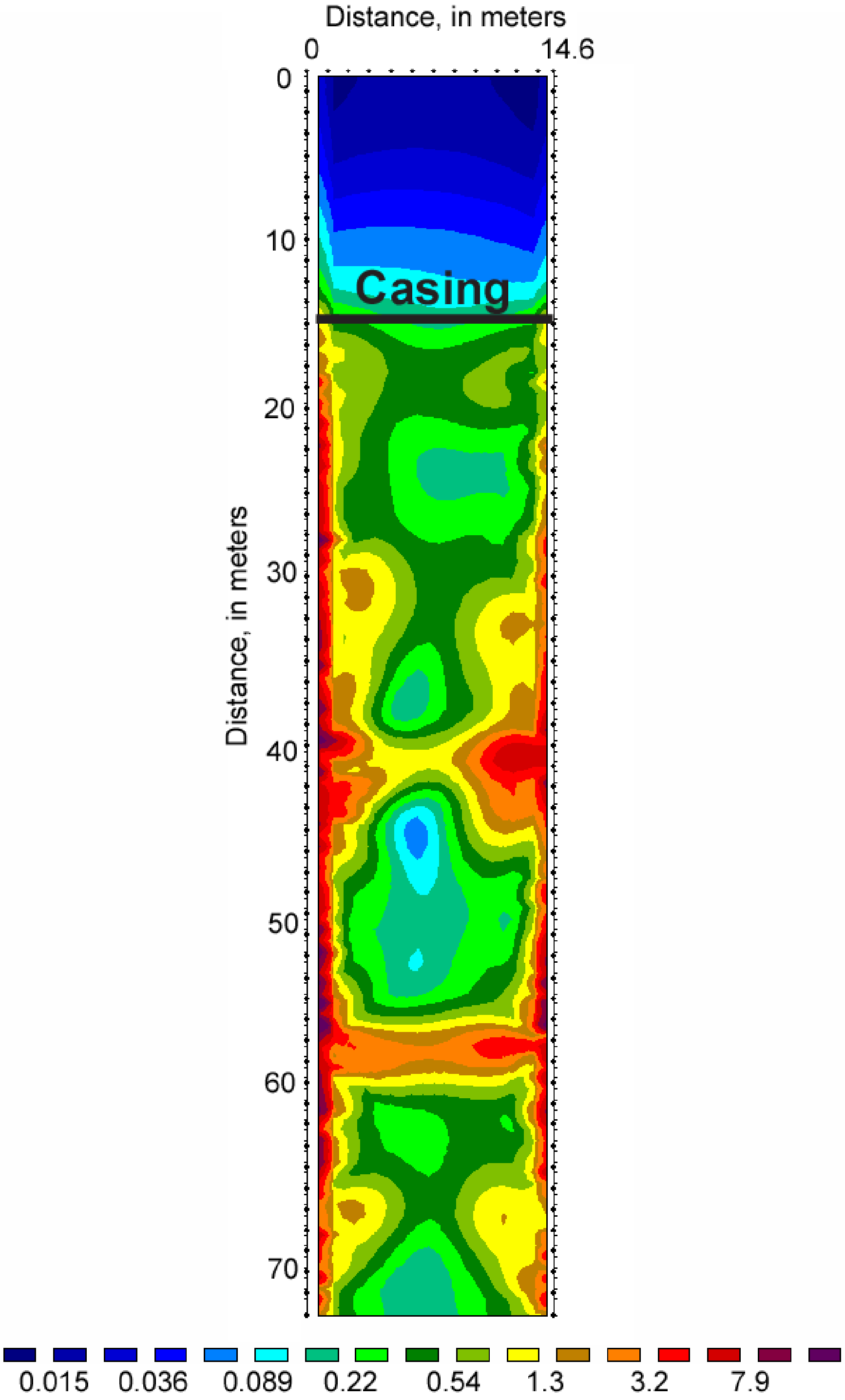


Figure 15. Relative sensitivity of the resistivity tomogram for the BM-34/BM-37 cross section. On the tomogram, borehole BM-34 is on the left and borehole BM-37 is on the right.

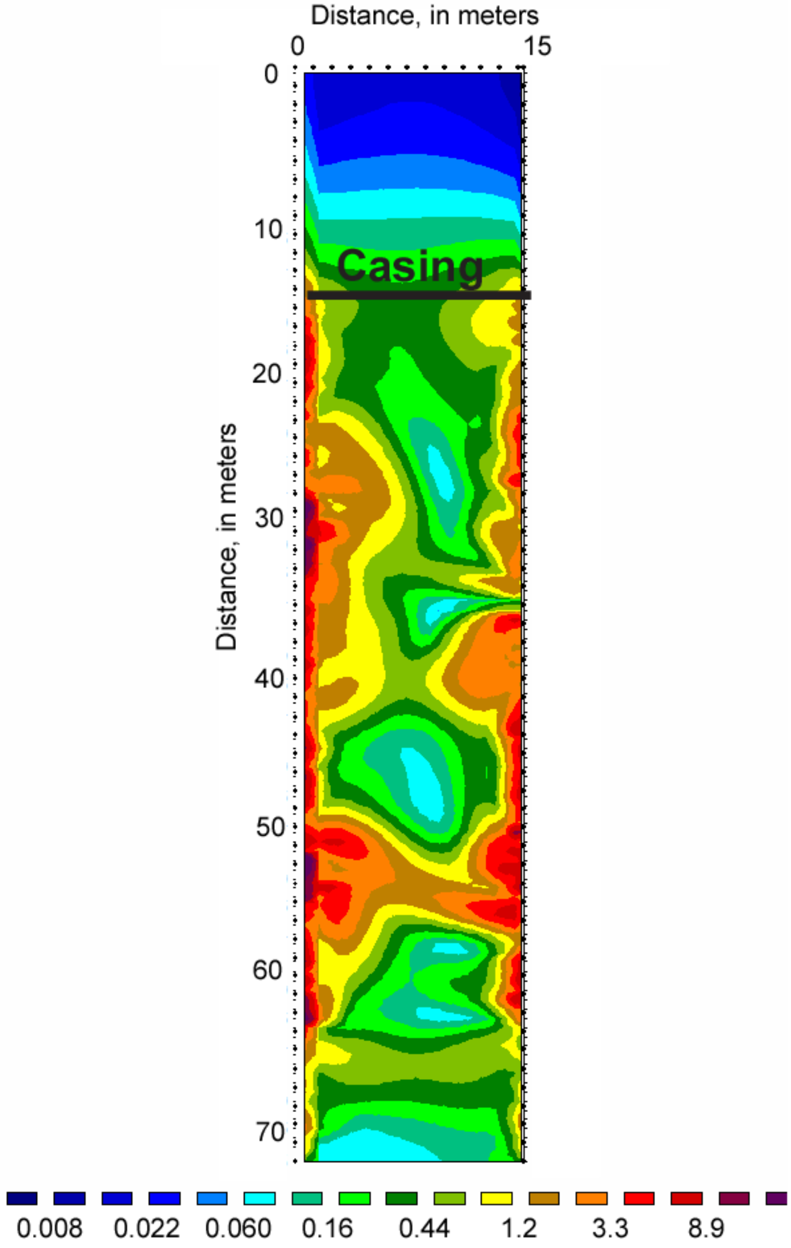


Figure 16. Relative sensitivity of the resistivity tomogram for the BM-37/BM-38 cross section. On the tomogram, borehole BM-37 is on the left and borehole BM-38 is on the right.

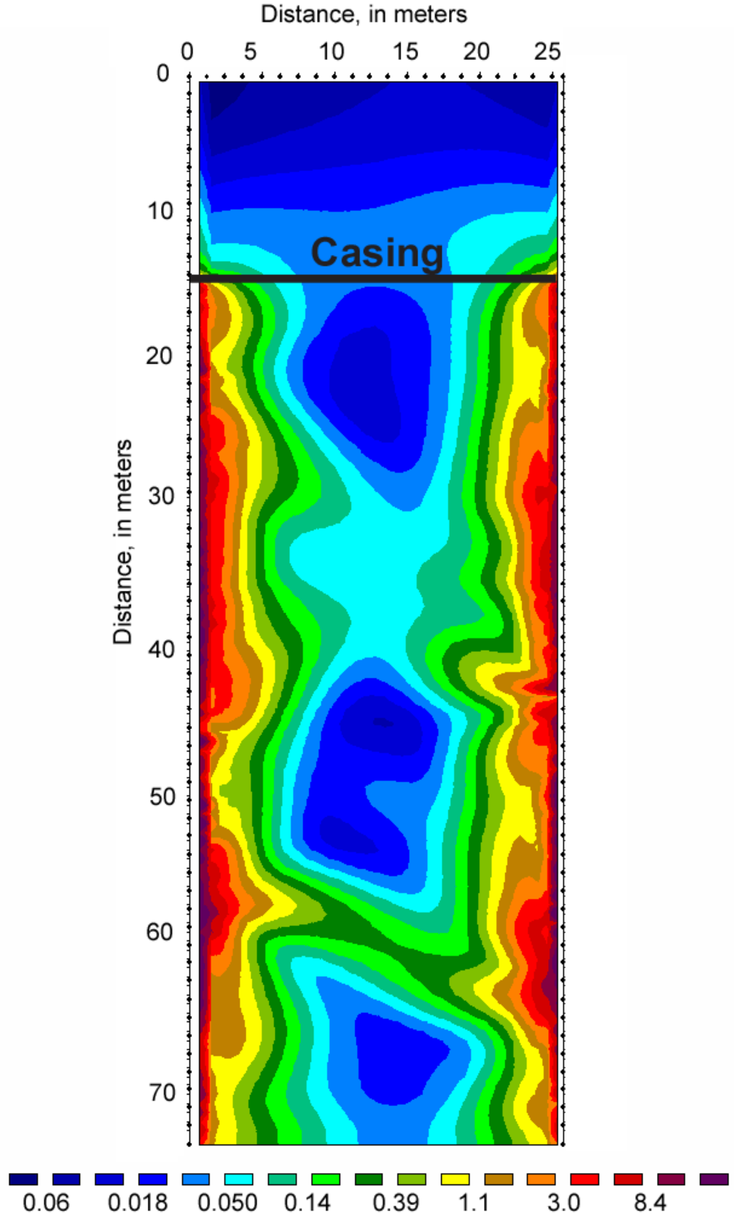


Figure 17. Relative sensitivity of the resistivity tomogram for the BM-34/BM-32 cross section. On the tomogram, borehole BM-34 is on the left and borehole BM-32 is on the right.

6. DISCUSSION

The data from Corinna exhibit large errors. Prior to editing, 40 percent of the full dataset had reciprocal or stacking errors larger than 3 percent or yielded negative values for apparent resistivity. Porosity in bedrock aquifers commonly is low (a few percent) and electrical resistivity can be very high (1,000-10,000 Ωm). In these settings, contact resistance is high, and it can be difficult to inject sufficient current to achieve a good signal-to-noise ratio. Working with electrode cables suspended in fluid-filled open holes can cause additional problems associated with current channeling inside wells. For measurements with in-well current dipoles (both current electrodes in the same well), current can channel preferentially travel through the electrically conductive water column rather than into the electrically resistive formation; these data may show small stacking and reciprocal errors but may, in fact, be highly spurious because such current channeling is not accounted for in the finite-difference or finite-element electrical simulation. Yet another challenge in applying ERI in fractured rock is that the features of interest (individual fractures of fracture zones) can be small relative to the resolution of the tomography (no better than the electrode spacing, or 1.25 m here). If large spatial variations in resistivity occur at sub-grid scale, the inversion may have a difficult time matching field data to a level consistent with the observed reciprocal error.

Inversions of the four 2-D tomographic datasets were unable to match the data to within observed reciprocal error; hence Occam inversion (section 4.1) was not possible. The final mean absolute errors for the four tomograms range from 11.3 to 28.6 percent, which are orders of magnitude larger than error indicated by reciprocal measurements (table 3). We note also that comparison of the tomograms generated from these data tend to show inconsistent resistivity values at borehole BM-38. Such inconsistency can result from measurement error or electrical anisotropy, in which case conductivity is directionally dependent. In the presence of electrical anisotropy, conductivity must be considered a tensor rather than scaler quantity; consideration of electrical anisotropy, however, is not available in Res2DInv or most commercially available resistivity inversion software. Because of the inability to fit 2D tomograms to the noisy data, more computationally intensive 3D inversion is not pursued here.

Table 3. Final mean absolute error for inversions.

	L1 mean absolute error
BM-34/BM-38	**11.3 percent**
BM-34/BM-37	**28.6 percent**
BM-37/BM-38	**28.6 percent**
BM-34/BM-32	**22.4 percent**

Despite the errors present in the Corinna dataset and the poor inversion results, the tomograms do show weak, qualitative correlation with transmissive features identified in borehole logs collected at the site (figs. 10-13). Fractures and transmissive zones were identified previously using a combination of borehole temperature, flowmeter, caliper, and televiewer logs conducted by Northeast Geophysical and provided to the USGS by Nobis Engineering, Inc.

Several important hydraulic features in the BM-37/BM-38, BM-34/BM-38, and BM-34/BM-37 planes are co-located with low resistivity anomalies (e.g., at about 41.5 m depth in the BM-34/BM-37 tomogram, and about 56.5 m depth in the BM-37/BM-38 tomogram), which would be consistent with regions of enhanced porosity or fracture density. We stress, however, that the correlation is weak and many transmissive features do not correspond to obvious anomalies in tomograms. Furthermore, because of large measurement errors and the inability of the inversion to match data closely, the location and magnitude of anomalies change substantially depending on the choice of inversion parameters. These results underscore the importance of corroborating borehole geophysical data and justifying parameter selection in the inversions before interpreting the tomograms.

Fractured rock settings have historically been difficult places to produce high quality electrical tomographic inversions. It may be that electromagnetic methods, such as borehole radar with its high spatial resolution may be more suitable for determining fracture location and connectivity between wellbores (Day-Lewis and others, 2003, 2004), although radar data tends to be more time-consuming and labor-intensive to collect and process.

7. CONCLUSIONS AND FUTURE DIRECTIONS

The goal of this work was to demonstrate and document best practices for ERT data collection and analysis. In summary, we provide guidelines in seven areas:

(1) *Survey geometry design*: The boreholes should be spaced such that electrode strings are at least twice as long vertically as their horizontal separation distance. The maximum offset between wells is further limited by the power of the resistivity unit and ability to inject sufficient current to achieve a good signal-to-noise ratio. Survey geometries should comprise both in-well and cross-well dipoles to capitalize on the sensitivity of each measurement and maximize the coverage of the tomogram.

(2) *Standard procedures for data collection*: Data collection and quality assurance and control should be documented using standardized forms and procedures.

(3) *Quantification of measurement error*: Standard and reciprocal errors should be collected in the field to assess the quality of the data, inform the editing of datasets, and calculate measurement weights for the inversion.

(4) *Selection of inversion parameters*: Existing data and geologic insight should be used to inform selection of inversion parameters. For datasets involving multiple planes, it is useful to apply multiple approaches to data from one plane, compare results, and design a consistent approach to inversion for data from across the site. Investigation of alternative inversion settings can aid in distinguishing artifacts from geologic features.

(5) *Checks on inversion results*: Tomograms should be evaluated for likely inversion artifacts and the effects of bad data. The practitioner should look at the range of estimated resistivity values for plausibility; pixilation (checkerboard) appearance of tomograms;

artifacts such as streaking, anomalous blocks, or diagonal patterns; and goodness of fit and convergence of the inversion.

(6) *Resolution assessment*: Results of tomograms should be compared with the sensitivity and (or) resolution matrix to assess the general quality of the tomogram.

(7) *Comparison to other information*: Tomograms should be compared to existing information, including geologic maps, lithology, borehole logs, and hydraulic tests. Borehole logs can provide information to help interpret features seen in tomograms and to help correlate estimated resistivity and lithology or hydraulic properties.

Our ERT results provide only limited insight into the distribution of fractures or fracture zones at the Corinna site. Fractured-rock aquifers represent challenging environments for ERT and conventional hydrologic characterization alike, as spatial variability is severe and occurs over a wide range of scales. Possible strategies to advance the capabilities of ERT for fractured-rock characterization include (1) use of electrode cables with smaller electrode spacing and more electrodes in order to improve resolution; (2) improved coupling between electrodes and borehole walls, using modified well constructions (e.g., with water-filled well liners) and dedicated electrodes; (3) improvements to ERT hardware to allow for higher driving voltages and applied currents, to improve the signal-to-noise ratio, (4) use of parameterizations and forward models appropriate for discrete-fracture networks, and (5) time-lapse imaging of electrically conductive (saline) tracers, which can reveal features not apparent in static tomograms (e.g., Day-Lewis and others, 2003, 2004; Singha and Gorelick, 2005). All of these strategies are areas of active research within the hydrogeophysical community. ERT hardware, software, and inversion strategies have evolved rapidly in recent years and continue to evolve, and further expansion of capabilities for characterization of fractured rock are likely. Faster data acquisition and computers, respectively, will facilitate full 3-D surveys and inversion. Although our results here are largely negative, this evaluation project should not be interpreted as a final statement on the ability of ERT to resolve important features in fractured rock; rather, we have highlighted the current limitations of the approach for a specific site and well configuration.

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Appendix 1. Sequence Files

Dipdip2d.txt

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7 0 0 36.25
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16  0 0 25
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27  30  31  29  32
28  31  32  30  33
29  32  33  31  34
30  33  34  32  35
31  34  35  33  36
32  35  36  34  37
33  36  37  35  38
34  37  38  36  39
35  38  39  37  40
36  39  40  38  41
37  40  41  39  42
38  41  42  40  43
39  42  43  41  44
40  43  44  42  45
41  44  45  43  46
42  45  46  44  47
43  46  47  45  48
44  3 5 1 7
45  4 6 2 8
46  5 7 3 9
47  6 8 4 10
48  7 9 5 11
49  8 10  6 12
50  9 11  7 13
51  10  12  8 14
52  11  13  9 15
53  12  14  10  16
54  13  15  11  17
55  14  16  12  18
56  15  17  13  19
57  16  18  14  20
58  17  19  15  21
```

```
59  18  20  16  22
60  19  21  17  23
61  20  22  18  24
62  27  29  25  31
63  28  30  26  32
64  29  31  27  33
65  30  32  28  34
66  31  33  29  35
67  32  34  30  36
68  33  35  31  37
69  34  36  32  38
70  35  37  33  39
71  36  38  34  40
72  37  39  35  41
73  38  40  36  42
74  39  41  37  43
75  40  42  38  44
76  41  43  39  45
77  42  44  40  46
78  43  45  41  47
79  44  46  42  48
```

dipdip2d_recip.txt

```
# X Y Z
1 0 0 43.75
2 0 0 42.5
3 0 0 41.25
4 0 0 40
5 0 0 38.75
6 0 0 37.5
7 0 0 36.25
8 0 0 35
9 0 0 33.75
10  0 0 32.5
11  0 0 31.25
12  0 0 30
13  0 0 28.75
14  0 0 27.5
15  0 0 26.25
16  0 0 25
17  0 0 23.75
18  0 0 22.5
19  0 0 21.25
20  0 0 20
```

```
21  0 0 18.75
22  0 0 17.5
23  0 0 16.25
24  0 0 15
25  14.6  0 15
26  14.6  0 16.25
27  14.6  0 17.5
28  14.6  0 18.75
29  14.6  0 20
30  14.6  0 21.25
31  14.6  0 22.5
32  14.6  0 23.75
33  14.6  0 25
34  14.6  0 26.25
35  14.6  0 27.5
36  14.6  0 28.75
37  14.6  0 30
38  14.6  0 31.25
39  14.6  0 32.5
40  14.6  0 33.75
41  14.6  0 35
42  14.6  0 36.25
43  14.6  0 37.5
44  14.6  0 38.75
45  14.6  0 40
46  14.6  0 41.25
47  14.6  0 42.5
48  14.6  0 43.75
# A B M N
1 22  26  24  25
2 26  21  24  25
3 21  27  24  25
4 27  20  24  25
5 20  28  24  25
6 28  19  24  25
7 19  29  24  25
8 29  18  24  25
9 18  30  24  25
10  17  31  24  25
11  31  16  24  25
12  16  32  24  25
13  32  15  24  25
14  15  33  24  25
15  33  14  24  25
16  14  34  24  25
17  34  13  24  25
18  13  35  24  25
```

```
19  12  36  24  25
20  36  11  24  25
21  11  37  24  25
22  37  10  24  25
23  10  38  24  25
24  38  9 24  25
25  9 39  24  25
26  39  8 24  25
27  8 40  24  25
28  7 41  24  25
29  41  6 24  25
30  6 42  24  25
31  42  5 24  25
32  5 43  24  25
33  43  4 24  25
34  4 44  24  25
35  44  3 24  25
36  3 45  24  25
37  2 46  24  25
38  46  23  24  25
39  23  47  24  25
40  47  1 24  25
41  1 48  24  25
42  48  21  24  25
43  21  27  22  26
44  27  20  22  26
45  20  28  22  26
46  28  19  22  26
47  19  29  22  26
48  29  18  22  26
49  18  30  22  26
50  30  17  22  26
51  17  31  22  26
52  31  16  22  26
53  16  32  22  26
54  32  15  22  26
55  15  33  22  26
56  33  14  22  26
57  14  34  22  26
58  34  13  22  26
59  13  35  22  26
60  35  12  22  26
61  12  36  22  26
62  36  11  22  26
63  11  37  22  26
64  37  10  22  26
65  10  38  22  26
```

```
66  38  9 22  26
67  9 39  22  26
68  39  8 22  26
69  8 40  22  26
70  40  7 22  26
71  7 41  22  26
72  41  6 22  26
73  6 42  22  26
74  42  5 22  26
75  5 43  22  26
76  43  4 22  26
77  4 44  22  26
78  44  3 22  26
79  3 45  22  26
80  45  2 22  26
81  2 46  22  26
82  46  23  22  26
83  23  47  22  26
84  47  1 22  26
85  1 48  22  26
86  48  20  22  26
87  20  28  21  27
88  28  19  21  27
89  19  29  21  27
90  29  18  21  27
91  18  30  21  27
92  30  17  21  27
93  17  31  21  27
94  31  16  21  27
95  16  32  21  27
96  32  15  21  27
97  15  33  21  27
98  33  14  21  27
99  14  34  21  27
100 34  13  21  27
101 13  35  21  27
102 35  12  21  27
103 12  36  21  27
104 36  11  21  27
105 11  37  21  27
106 37  10  21  27
107 10  38  21  27
108 38  9 21  27
109 9 39  21  27
110 39  8 21  27
111 8 40  21  27
112 40  7 21  27
```

```
113 7 41  21  27
114 41  6 21  27
115 6 42  21  27
116 42  5 21  27
117 5 43  21  27
118 43  4 21  27
119 4 44  21  27
120 44  3 21  27
121 3 45  21  27
122 45  2 21  27
123 2 46  21  27
124 46  23  21  27
125 23  47  21  27
126 47  1 21  27
127 1 48  21  27
128 48  19  21  27
129 19  29  20  28
130 29  18  20  28
131 18  30  20  28
132 30  17  20  28
133 17  31  20  28
134 31  16  20  28
135 16  32  20  28
136 32  15  20  28
137 15  33  20  28
138 33  14  20  28
139 14  34  20  28
140 34  13  20  28
141 13  35  20  28
142 35  12  20  28
143 12  36  20  28
144 36  11  20  28
145 11  37  20  28
146 37  10  20  28
147 10  38  20  28
148 38  9 20  28
149 9 39  20  28
150 39  8 20  28
151 8 40  20  28
152 40  7 20  28
153 7 41  20  28
154 41  6 20  28
155 6 42  20  28
156 42  5 20  28
157 5 43  20  28
158 43  4 20  28
159 4 44  20  28
```

```
160 44  3 20  28
161 3 45  20  28
162 45  2 20  28
163 2 46  20  28
164 46  23  20  28
165 23  47  20  28
166 47  1 20  28
167 1 48  20  28
168 48  18  20  28
169 18  30  19  29
170 30  17  19  29
171 17  31  19  29
172 31  16  19  29
173 16  32  19  29
174 32  15  19  29
175 15  33  19  29
176 33  14  19  29
177 14  34  19  29
178 34  13  19  29
179 13  35  19  29
180 35  12  19  29
181 12  36  19  29
182 36  11  19  29
183 11  37  19  29
184 37  10  19  29
185 10  38  19  29
186 38  9 19  29
187 9 39  19  29
188 39  8 19  29
189 8 40  19  29
190 40  7 19  29
191 7 41  19  29
192 41  6 19  29
193 6 42  19  29
194 42  5 19  29
195 5 43  19  29
196 43  4 19  29
197 4 44  19  29
198 44  3 19  29
199 3 45  19  29
200 45  2 19  29
201 2 46  19  29
202 46  23  19  29
203 23  47  19  29
204 47  1 19  29
205 1 48  19  29
206 48  17  19  29
```

```
207 17  31  18  30
208 31  16  18  30
209 16  32  18  30
210 32  15  18  30
211 15  33  18  30
212 33  14  18  30
213 14  34  18  30
214 34  13  18  30
215 13  35  18  30
216 35  12  18  30
217 12  36  18  30
218 36  11  18  30
219 11  37  18  30
220 37  10  18  30
221 10  38  18  30
222 38  9 18  30
223 9 39  18  30
224 39  8 18  30
225 8 40  18  30
226 40  7 18  30
227 7 41  18  30
228 41  6 18  30
229 6 42  18  30
230 42  5 18  30
231 5 43  18  30
232 43  4 18  30
233 4 44  18  30
234 44  3 18  30
235 3 45  18  30
236 45  2 18  30
237 2 46  18  30
238 46  23  18  30
239 23  47  18  30
240 47  1 18  30
241 1 48  18  30
242 48  16  18  30
243 16  32  17  31
244 32  15  17  31
245 15  33  17  31
246 33  14  17  31
247 14  34  17  31
248 34  13  17  31
249 13  35  17  31
250 35  12  17  31
251 12  36  17  31
252 36  11  17  31
253 11  37  17  31
```

```
254 37  10  17  31
255 10  38  17  31
256 38  9 17  31
257 9 39  17  31
258 39  8 17  31
259 8 40  17  31
260 40  7 17  31
261 7 41  17  31
262 41  6 17  31
263 6 42  17  31
264 42  5 17  31
265 5 43  17  31
266 43  4 17  31
267 4 44  17  31
268 44  3 17  31
269 3 45  17  31
270 45  2 17  31
271 2 46  17  31
272 46  23  17  31
273 23  47  17  31
274 47  1 17  31
275 1 48  17  31
276 48  15  17  31
277 15  33  16  32
278 33  14  16  32
279 14  34  16  32
280 34  13  16  32
281 13  35  16  32
282 35  12  16  32
283 12  36  16  32
284 36  11  16  32
285 11  37  16  32
286 37  10  16  32
287 10  38  16  32
288 38  9 16  32
289 9 39  16  32
290 39  8 16  32
291 8 40  16  32
292 40  7 16  32
293 7 41  16  32
294 41  6 16  32
295 6 42  16  32
296 42  5 16  32
297 5 43  16  32
298 43  4 16  32
299 4 44  16  32
300 44  3 16  32
```

```
301 3 45  16  32
302 45  2 16  32
303 2 46  16  32
304 46  23  16  32
305 23  47  16  32
306 47  1 16  32
307 1 48  16  32
308 48  14  16  32
309 14  34  15  33
310 34  13  15  33
311 13  35  15  33
312 35  12  15  33
313 12  36  15  33
314 36  11  15  33
315 11  37  15  33
316 37  10  15  33
317 10  38  15  33
318 38  9 15  33
319 9 39  15  33
320 39  8 15  33
321 8 40  15  33
322 40  7 15  33
323 7 41  15  33
324 41  6 15  33
325 6 42  15  33
326 42  5 15  33
327 5 43  15  33
328 43  4 15  33
329 4 44  15  33
330 44  3 15  33
331 3 45  15  33
332 45  2 15  33
333 2 46  15  33
334 46  23  15  33
335 23  47  15  33
336 47  1 15  33
337 1 48  15  33
338 48  13  15  33
339 13  35  14  34
340 35  12  14  34
341 12  36  14  34
342 36  11  14  34
343 11  37  14  34
344 37  10  14  34
345 10  38  14  34
346 38  9 14  34
347 9 39  14  34
```

```
348 39  8 14  34
349 8 40  14  34
350 40  7 14  34
351 7 41  14  34
352 41  6 14  34
353 6 42  14  34
354 42  5 14  34
355 5 43  14  34
356 43  4 14  34
357 4 44  14  34
358 44  3 14  34
359 3 45  14  34
360 45  2 14  34
361 2 46  14  34
362 46  23  14  34
363 23  47  14  34
364 47  1 14  34
365 1 48  14  34
366 48  12  14  34
367 12  36  13  35
368 36  11  13  35
369 11  37  13  35
370 37  10  13  35
371 10  38  13  35
372 38  9 13  35
373 9 39  13  35
374 39  8 13  35
375 8 40  13  35
376 40  7 13  35
377 7 41  13  35
378 41  6 13  35
379 6 42  13  35
380 42  5 13  35
381 5 43  13  35
382 43  4 13  35
383 4 44  13  35
384 44  3 13  35
385 3 45  13  35
386 45  2 13  35
387 2 46  13  35
388 46  23  13  35
389 23  47  13  35
390 47  1 13  35
391 1 48  13  35
392 48  11  13  35
393 11  37  12  36
394 37  10  12  36
```

```
395 10  38  12  36
396 38  9 12  36
397 9 39  12  36
398 39  8 12  36
399 8 40  12  36
400 40  7 12  36
401 7 41  12  36
402 41  6 12  36
403 6 42  12  36
404 42  5 12  36
405 5 43  12  36
406 43  4 12  36
407 4 44  12  36
408 44  3 12  36
409 3 45  12  36
410 45  2 12  36
411 2 46  12  36
412 46  23  12  36
413 23  47  12  36
414 47  1 12  36
415 1 48  12  36
416 48  10  12  36
417 10  38  11  37
418 38  9 11  37
419 9 39  11  37
420 39  8 11  37
421 8 40  11  37
422 40  7 11  37
423 7 41  11  37
424 41  6 11  37
425 6 42  11  37
426 42  5 11  37
427 5 43  11  37
428 43  4 11  37
429 4 44  11  37
430 44  3 11  37
431 3 45  11  37
432 45  2 11  37
433 2 46  11  37
434 46  23  11  37
435 23  47  11  37
436 47  1 11  37
437 1 48  11  37
438 48  9 11  37
439 9 39  10  38
440 39  8 10  38
441 8 40  10  38
```

```
442 40  7 10  38
443 7 41  10  38
444 41  6 10  38
445 6 42  10  38
446 42  5 10  38
447 5 43  10  38
448 43  4 10  38
449 4 44  10  38
450 44  3 10  38
451 3 45  10  38
452 45  2 10  38
453 2 46  10  38
454 46  23  10  38
455 23  47  10  38
456 47  1 10  38
457 1 48  10  38
458 48  8 10  38
459 8 40  9 39
460 40  7 9 39
461 7 41  9 39
462 41  6 9 39
463 6 42  9 39
464 42  5 9 39
465 5 43  9 39
466 43  4 9 39
467 4 44  9 39
468 44  3 9 39
469 3 45  9 39
470 45  2 9 39
471 2 46  9 39
472 46  23  9 39
473 23  47  9 39
474 47  1 9 39
475 1 48  9 39
476 48  7 9 39
477 7 41  8 40
478 41  6 8 40
479 6 42  8 40
480 42  5 8 40
481 5 43  8 40
482 43  4 8 40
483 4 44  8 40
484 44  3 8 40
485 3 45  8 40
486 45  2 8 40
487 2 46  8 40
488 46  23  8 40
```

```
489 23  47  8 40
490 47  1 8 40
491 1 48  8 40
492 48  6 8 40
493 6 42  7 41
494 42  5 7 41
495 5 43  7 41
496 43  4 7 41
497 4 44  7 41
498 44  3 7 41
499 3 45  7 41
500 45  2 7 41
501 2 46  7 41
502 46  23  7 41
503 23  47  7 41
504 47  1 7 41
505 1 48  7 41
506 48  5 7 41
507 5 43  6 42
508 43  4 6 42
509 4 44  6 42
510 44  3 6 42
511 3 45  6 42
512 45  2 6 42
513 2 46  6 42
514 46  23  6 42
515 23  47  6 42
516 47  1 6 42
517 1 48  6 42
518 48  4 6 42
519 4 44  5 43
520 44  3 5 43
521 3 45  5 43
522 45  2 5 43
523 2 46  5 43
524 46  23  5 43
525 23  47  5 43
526 47  1 5 43
527 1 48  5 43
528 48  3 5 43
529 3 45  4 44
530 45  2 4 44
531 2 46  4 44
532 46  23  4 44
533 23  47  4 44
534 47  1 4 44
535 1 48  4 44
```

```
536 48  2 4 44
537 2 46  3 45
538 46  23  3 45
539 23  47  3 45
540 47  1 3 45
541 1 48  3 45
542 48  23  3 45
543 23  47  2 46
544 47  1 2 46
545 1 48  2 46
546 48  1 23  47
1 1 4 2 3
2 2 5 3 4
3 3 6 4 5
4 4 7 5 6
5 5 8 6 7
6 6 9 7 8
7 7 10  8 9
8 8 11  9 10
9 9 12  10  11
10  10  13  11  12
11  11  14  12  13
12  12  15  13  14
13  13  16  14  15
14  14  17  15  16
15  15  18  16  17
16  16  19  17  18
17  17  20  18  19
18  18  21  19  20
19  19  22  20  21
20  20  23  21  22
21  21  24  22  23
22  24  27  25  26
23  25  28  26  27
24  26  29  27  28
25  27  30  28  29
26  28  31  29  30
27  29  32  30  31
28  30  33  31  32
29  31  34  32  33
30  32  35  33  34
31  33  36  34  35
32  34  37  35  36
33  35  38  36  37
34  36  39  37  38
35  37  40  38  39
36  38  41  39  40
```

```
37  39  42  40  41
38  40  43  41  42
39  41  44  42  43
40  42  45  43  44
41  43  46  44  45
42  44  47  45  46
43  45  48  46  47
44  1 7 3 5
45  2 8 4 6
46  3 9 5 7
47  4 10  6 8
48  5 11  7 9
49  6 12  8 10
50  7 13  9 11
51  8 14  10  12
52  9 15  11  13
53  10  16  12  14
54  11  17  13  15
55  12  18  14  16
56  13  19  15  17
57  14  20  16  18
58  15  21  17  19
59  16  22  18  20
60  17  23  19  21
61  18  24  20  22
62  25  31  27  29
63  26  32  28  30
64  27  33  29  31
65  28  34  30  32
66  29  35  31  33
67  30  36  32  34
68  31  37  33  35
69  32  38  34  36
70  33  39  35  37
71  34  40  36  38
72  35  41  37  39
73  36  42  38  40
74  37  43  39  41
75  38  44  40  42
76  39  45  41  43
77  40  46  42  44
78  41  47  43  45
79  42  48  44  46
```

dipdip3d.txt

```
# X Y Z
1 0 0 43.75
2 0 0 42.5
3 0 0 41.25
4 0 0 40
5 0 0 38.75
6 0 0 37.5
7 0 0 36.25
8 0 0 35
9 0 0 33.75
10  0 0 32.5
11  0 0 31.25
12  0 0 30
13  0 0 28.75
14  0 0 27.5
15  0 0 26.25
16  0 0 25
17  0 0 23.75
18  0 0 22.5
19  0 0 21.25
20  0 0 20
21  0 0 18.75
22  0 0 17.5
23  0 0 16.25
24  0 0 15
25  14.6  0 15
26  14.6  0 16.25
27  14.6  0 17.5
28  14.6  0 18.75
29  14.6  0 20
30  14.6  0 21.25
31  14.6  0 22.5
32  14.6  0 23.75
33  14.6  0 25
34  14.6  0 26.25
35  14.6  0 27.5
36  14.6  0 28.75
37  14.6  0 30
38  14.6  0 31.25
39  14.6  0 32.5
40  14.6  0 33.75
41  14.6  0 35
42  14.6  0 36.25
43  14.6  0 37.5
44  14.6  0 38.75
45  14.6  0 40
46  14.6  0 41.25
```

```
47  14.6  0 42.5
48  14.6  0 43.75
49  25  0 15
50  25  0 16.25
51  25  0 17.5
52  25  0 18.75
53  25  0 20
54  25  0 21.25
55  25  0 22.5
56  25  0 23.75
57  25  0 25
58  25  0 26.25
59  25  0 27.5
60  25  0 28.75
61  25  0 30
62  25  0 31.25
63  25  0 32.5
64  25  0 33.75
65  25  0 35
66  25  0 36.25
67  25  0 37.5
68  25  0 38.75
69  25  0 40
70  25  0 41.25
71  25  0 42.5
72  25  0 43.75
# A B M N
1 24  49  23  50
2 24  49  50  22
3 24  49  22  51
4 24  49  51  21
5 24  49  21  52
6 24  49  52  20
7 24  49  20  53
8 24  49  53  19
9 24  49  19  54
10  24  49  18  55
11  24  49  55  17
12  24  49  17  56
13  24  49  56  16
14  24  49  16  57
15  24  49  57  15
16  24  49  15  58
17  24  49  58  14
18  24  49  14  59
19  24  49  13  60
20  24  49  60  12
```

```
21  24  49  12  61
22  24  49  61  11
23  24  49  11  62
24  24  49  62  10
25  24  49  10  63
26  24  49  63  9
27  24  49  9 64
28  24  49  8 65
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dipdip3drecip.txt

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5 0 0 38.75
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7 0 0 36.25
8 0 0 35
9 0 0 33.75
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11  0 0 31.25
12  0 0 30
13  0 0 28.75
14  0 0 27.5
15  0 0 26.25
16  0 0 25
17  0 0 23.75
18  0 0 22.5
19  0 0 21.25
20  0 0 20
21  0 0 18.75
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23  0 0 16.25
24  0 0 15
25  14.6  0 15
26  14.6  0 16.25
27  14.6  0 17.5
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531 46  70  44  68
532 70  23  44  68
533 23  71  44  68
534 71  48  44  68
535 48  72  44  68
536 72  46  44  68
537 46  70  45  69
538 70  23  45  69
539 23  71  45  69
540 71  48  45  69
541 48  72  45  69
542 72  23  45  69
543 23  71  46  70
544 71  48  46  70
545 48  72  46  70
546 72  48  23  71
# A B M N
1 1 4 2 3
```

```
2 2 5 3 4
3 3 6 4 5
4 4 7 5 6
5 5 8 6 7
6 6 9 7 8
7 7 10  8 9
8 8 11  9 10
9 9 12  10  11
10  10  13  11  12
11  11  14  12  13
12  12  15  13  14
13  13  16  14  15
14  14  17  15  16
15  15  18  16  17
16  16  19  17  18
17  17  20  18  19
18  18  21  19  20
19  19  22  20  21
20  20  23  21  22
21  21  24  22  23
22  24  27  25  26
23  25  28  26  27
24  26  29  27  28
25  27  30  28  29
26  28  31  29  30
27  29  32  30  31
28  30  33  31  32
29  31  34  32  33
30  32  35  33  34
31  33  36  34  35
32  34  37  35  36
33  35  38  36  37
34  36  39  37  38
35  37  40  38  39
36  38  41  39  40
37  39  42  40  41
38  40  43  41  42
39  41  44  42  43
40  42  45  43  44
41  43  46  44  45
42  44  47  45  46
43  45  48  46  47
44  49  52  50  51
45  50  53  51  52
46  51  54  52  53
47  52  55  53  54
48  53  56  54  55
```

```
49  54  57  55  56
50  55  58  56  57
51  56  59  57  58
52  57  60  58  59
53  58  61  59  60
54  59  62  60  61
55  60  63  61  62
56  61  64  62  63
57  62  65  63  64
58  63  66  64  65
59  64  67  65  66
60  65  68  66  67
61  66  69  67  68
62  67  70  68  69
63  68  71  69  70
64  69  72  70  71
65  1 7 3 5
66  2 8 4 6
67  3 9 5 7
68  4 10  6 8
69  5 11  7 9
70  6 12  8 10
71  7 13  9 11
72  8 14  10  12
73  9 15  11  13
74  10  16  12  14
75  11  17  13  15
76  12  18  14  16
77  13  19  15  17
78  14  20  16  18
79  15  21  17  19
80  16  22  18  20
81  17  23  19  21
82  18  24  20  22
83  25  31  27  29
84  26  32  28  30
85  27  33  29  31
86  28  34  30  32
87  29  35  31  33
88  30  36  32  34
89  31  37  33  35
90  32  38  34  36
91  33  39  35  37
92  34  40  36  38
93  35  41  37  39
94  36  42  38  40
95  37  43  39  41
```

```
96  38  44  40  42
97  39  45  41  43
98  40  46  42  44
99  41  47  43  45
100 42  48  44  46
101 49  55  51  53
102 50  56  52  54
103 51  57  53  55
104 52  58  54  56
105 53  59  55  57
106 54  60  56  58
107 55  61  57  59
108 56  62  58  60
109 57  63  59  61
110 58  64  60  62
111 59  65  61  63
112 60  66  62  64
113 61  67  63  65
114 62  68  64  66
115 63  69  65  67
116 64  70  66  68
117 65  71  67  69
118 66  72  68  70
```

wenner2d.txt

```
# A B M N
1 2 3 1 4
2 3 4 2 5
3 4 5 3 6
4 5 6 4 7
5 6 7 5 8
6 7 8 6 9
7 8 9 7 10
8 9 10  8 11
9 10  11  9 12
10  11  12  10  13
11  12  13  11  14
12  13  14  12  15
13  14  15  13  16
14  15  16  14  17
15  16  17  15  18
16  17  18  16  19
17  18  19  17  20
18  19  20  18  21
19  20  21  19  22
```

```
20  21  22  20  23
21  22  23  21  24
22  25  26  24  27
23  26  27  25  28
24  27  28  26  29
25  28  29  27  30
26  29  30  28  31
27  30  31  29  32
28  31  32  30  33
29  32  33  31  34
30  33  34  32  35
31  34  35  33  36
32  35  36  34  37
33  36  37  35  38
34  37  38  36  39
35  38  39  37  40
36  39  40  38  41
37  40  41  39  42
38  41  42  40  43
39  42  43  41  44
40  43  44  42  45
41  44  45  43  46
42  45  46  44  47
43  46  47  45  48
44  3 5 1 7
45  4 6 2 8
46  5 7 3 9
47  6 8 4 10
48  7 9 5 11
49  8 10  6 12
50  9 11  7 13
51  10  12  8 14
52  11  13  9 15
53  12  14  10  16
54  13  15  11  17
55  14  16  12  18
56  15  17  13  19
57  16  18  14  20
58  17  19  15  21
59  18  20  16  22
60  19  21  17  23
61  20  22  18  24
62  27  29  25  31
63  28  30  26  32
64  29  31  27  33
65  30  32  28  34
66  31  33  29  35
```

```
67  32  34  30  36
68  33  35  31  37
69  34  36  32  38
70  35  37  33  39
71  36  38  34  40
72  37  39  35  41
73  38  40  36  42
74  39  41  37  43
75  40  42  38  44
76  41  43  39  45
77  42  44  40  46
78  43  45  41  47
79  44  46  42  48
```

wenner2drecip.txt

```
# A B M N
1 1 4 2 3
2 2 5 3 4
3 3 6 4 5
4 4 7 5 6
5 5 8 6 7
6 6 9 7 8
7 7 10 8 9
8 8 11 9 10
9 9 12 10 11
10 10 13 11 12
11 11 14 12 13
12 12 15 13 14
13 13 16 14 15
14 14 17 15 16
15 15 18 16 17
16 16 19 17 18
17 17 20 18 19
18 18 21 19 20
19 19 22 20 21
20 20 23 21 22
21 21 24 22 23
22 24 27 25 26
23 25 28 26 27
24 26 29 27 28
25 27 30 28 29
26 28 31 29 30
27 29 32 30 31
```

```
28 30 33 31 32
29 31 34 32 33
30 32 35 33 34
31 33 36 34 35
32 34 37 35 36
33 35 38 36 37
34 36 39 37 38
35 37 40 38 39
36 38 41 39 40
37 39 42 40 41
38 40 43 41 42
39 41 44 42 43
40 42 45 43 44
41 43 46 44 45
42 44 47 45 46
43 45 48 46 47
44 1  7  3  5
45 2  8  4  6
46 3  9  5  7
47 4  10 6  8
48 5  11 7  9
49 6  12 8  10
50 7  13 9  11
51 8  14 10 12
52 9  15 11 13
53 10 16 12 14
54 11 17 13 15
55 12 18 14 16
56 13 19 15 17
57 14 20 16 18
58 15 21 17 19
59 16 22 18 20
60 17 23 19 21
61 18 24 20 22
62 25 31 27 29
63 26 32 28 30
64 27 33 29 31
65 28 34 30 32
66 29 35 31 33
67 30 36 32 34
68 31 37 33 35
69 32 38 34 36
70 33 39 35 37
71 34 40 36 38
72 35 41 37 39
73 36 42 38 40
```

```
74 37 43 39 41
75 38 44 40 42
76 39 45 41 43
77 40 46 42 44
78 41 47 43 45
79 42 48 44 46
```

wenner3d.txt

```
# X Y Z
1 0 0 43.75
2 0 0 42.5
3 0 0 41.25
4 0 0 40
5 0 0 38.75
6 0 0 37.5
7 0 0 36.25
8 0 0 35
9 0 0 33.75
10  0 0 32.5
11  0 0 31.25
12  0 0 30
13  0 0 28.75
14  0 0 27.5
15  0 0 26.25
16  0 0 25
17  0 0 23.75
18  0 0 22.5
19  0 0 21.25
20  0 0 20
21  0 0 18.75
22  0 0 17.5
23  0 0 16.25
24  0 0 15
25  14.6  0 15
26  14.6  0 16.25
27  14.6  0 17.5
28  14.6  0 18.75
29  14.6  0 20
30  14.6  0 21.25
31  14.6  0 22.5
32  14.6  0 23.75
33  14.6  0 25
```

```
34  14.6  0 26.25
35  14.6  0 27.5
36  14.6  0 28.75
37  14.6  0 30
38  14.6  0 31.25
39  14.6  0 32.5
40  14.6  0 33.75
41  14.6  0 35
42  14.6  0 36.25
43  14.6  0 37.5
44  14.6  0 38.75
45  14.6  0 40
46  14.6  0 41.25
47  14.6  0 42.5
48  14.6  0 43.75
49  25  0 15
50  25  0 16.25
51  25  0 17.5
52  25  0 18.75
53  25  0 20
54  25  0 21.25
55  25  0 22.5
56  25  0 23.75
57  25  0 25
58  25  0 26.25
59  25  0 27.5
60  25  0 28.75
61  25  0 30
62  25  0 31.25
63  25  0 32.5
64  25  0 33.75
65  25  0 35
66  25  0 36.25
67  25  0 37.5
68  25  0 38.75
69  25  0 40
70  25  0 41.25
71  25  0 42.5
72  25  0 43.75
# A B M N
1 2 3 1 4
2 3 4 2 5
3 4 5 3 6
4 5 6 4 7
5 6 7 5 8
6 7 8 6 9
7 8 9 7 10
```

```
8 9 10  8 11
9 10  11  9 12
10  11  12  10  13
11  12  13  11  14
12  13  14  12  15
13  14  15  13  16
14  15  16  14  17
15  16  17  15  18
16  17  18  16  19
17  18  19  17  20
18  19  20  18  21
19  20  21  19  22
20  21  22  20  23
21  22  23  21  24
22  25  26  24  27
23  26  27  25  28
24  27  28  26  29
25  28  29  27  30
26  29  30  28  31
27  30  31  29  32
28  31  32  30  33
29  32  33  31  34
30  33  34  32  35
31  34  35  33  36
32  35  36  34  37
33  36  37  35  38
34  37  38  36  39
35  38  39  37  40
36  39  40  38  41
37  40  41  39  42
38  41  42  40  43
39  42  43  41  44
40  43  44  42  45
41  44  45  43  46
42  45  46  44  47
43  46  47  45  48
44  50  51  49  52
45  51  52  50  53
46  52  53  51  54
47  53  54  52  55
48  54  55  53  56
49  55  56  54  57
50  56  57  55  58
51  57  58  56  59
52  58  59  57  60
53  59  60  58  61
54  60  61  59  62
```

```
55  61  62  60  63
56  62  63  61  64
57  63  64  62  65
58  64  65  63  66
59  65  66  64  67
60  66  67  65  68
61  67  68  66  69
62  68  69  67  70
63  69  70  68  71
64  70  71  69  72
65  3 5 1 7
66  4 6 2 8
67  5 7 3 9
68  6 8 4 10
69  7 9 5 11
70  8 10  6 12
71  9 11  7 13
72  10  12  8 14
73  11  13  9 15
74  12  14  10  16
75  13  15  11  17
76  14  16  12  18
77  15  17  13  19
78  16  18  14  20
79  17  19  15  21
80  18  20  16  22
81  19  21  17  23
82  20  22  18  24
83  27  29  25  31
84  28  30  26  32
85  29  31  27  33
86  30  32  28  34
87  31  33  29  35
88  32  34  30  36
89  33  35  31  37
90  34  36  32  38
91  35  37  33  39
92  36  38  34  40
93  37  39  35  41
94  38  40  36  42
95  39  41  37  43
96  40  42  38  44
97  41  43  39  45
98  42  44  40  46
99  43  45  41  47
100 44  46  42  48
101 51  53  49  55
```

```
102 52  54  50  56
103 53  55  51  57
104 54  56  52  58
105 55  57  53  59
106 56  58  54  60
107 57  59  55  61
108 58  60  56  62
109 59  61  57  63
110 60  62  58  64
111 61  63  59  65
112 62  64  60  66
113 63  65  61  67
114 64  66  62  68
115 65  67  63  69
116 66  68  64  70
117 67  69  65  71
118 68  70  66  72
```

wenner3drecip.txt

```
#  X  Y  Z
1  0  0  43.75
2  0  0  42.5
3  0  0  41.25
4  0  0  40
5  0  0  38.75
6  0  0  37.5
7  0  0  36.25
8  0  0  35
9  0  0  33.75
10 0  0  32.5
11 0  0  31.25
12 0  0  30
13 0  0  28.75
14 0  0  27.5
15 0  0  26.25
16 0  0  25
17 0  0  23.75
18 0  0  22.5
19 0  0  21.25
20 0  0  20
21 0  0  18.75
22 0  0  17.5
23 0  0  16.25
```

```
24 0   0   15
25 14.6   0   15
26 14.6   0   16.25
27 14.6   0   17.5
28 14.6   0   18.75
29 14.6   0   20
30 14.6   0   21.25
31 14.6   0   22.5
32 14.6   0   23.75
33 14.6   0   25
34 14.6   0   26.25
35 14.6   0   27.5
36 14.6   0   28.75
37 14.6   0   30
38 14.6   0   31.25
39 14.6   0   32.5
40 14.6   0   33.75
41 14.6   0   35
42 14.6   0   36.25
43 14.6   0   37.5
44 14.6   0   38.75
45 14.6   0   40
46 14.6   0   41.25
47 14.6   0   42.5
48 14.6   0   43.75
49 25 0   15
50 25 0   16.25
51 25 0   17.5
52 25 0   18.75
53 25 0   20
54 25 0   21.25
55 25 0   22.5
56 25 0   23.75
57 25 0   25
58 25 0   26.25
59 25 0   27.5
60 25 0   28.75
61 25 0   30
62 25 0   31.25
63 25 0   32.5
64 25 0   33.75
65 25 0   35
66 25 0   36.25
67 25 0   37.5
68 25 0   38.75
69 25 0   40
```

```
70 25 0  41.25
71 25 0  42.5
72 25 0  43.75
#  A  B  M  N
1  1  4  2  3
2  2  5  3  4
3  3  6  4  5
4  4  7  5  6
5  5  8  6  7
6  6  9  7  8
7  7  10 8  9
8  8  11 9  10
9  9  12 10 11
10 10 13 11 12
11 11 14 12 13
12 12 15 13 14
13 13 16 14 15
14 14 17 15 16
15 15 18 16 17
16 16 19 17 18
17 17 20 18 19
18 18 21 19 20
19 19 22 20 21
20 20 23 21 22
21 21 24 22 23
22 24 27 25 26
23 25 28 26 27
24 26 29 27 28
25 27 30 28 29
26 28 31 29 30
27 29 32 30 31
28 30 33 31 32
29 31 34 32 33
30 32 35 33 34
31 33 36 34 35
32 34 37 35 36
33 35 38 36 37
34 36 39 37 38
35 37 40 38 39
36 38 41 39 40
37 39 42 40 41
38 40 43 41 42
39 41 44 42 43
40 42 45 43 44
41 43 46 44 45
42 44 47 45 46
```

```
43 45 48 46 47
44 49 52 50 51
45 50 53 51 52
46 51 54 52 53
47 52 55 53 54
48 53 56 54 55
49 54 57 55 56
50 55 58 56 57
51 56 59 57 58
52 57 60 58 59
53 58 61 59 60
54 59 62 60 61
55 60 63 61 62
56 61 64 62 63
57 62 65 63 64
58 63 66 64 65
59 64 67 65 66
60 65 68 66 67
61 66 69 67 68
62 67 70 68 69
63 68 71 69 70
64 69 72 70 71
65 1  7  3  5
66 2  8  4  6
67 3  9  5  7
68 4  10 6  8
69 5  11 7  9
70 6  12 8  10
71 7  13 9  11
72 8  14 10 12
73 9  15 11 13
74 10 16 12 14
75 11 17 13 15
76 12 18 14 16
77 13 19 15 17
78 14 20 16 18
79 15 21 17 19
80 16 22 18 20
81 17 23 19 21
82 18 24 20 22
83 25 31 27 29
84 26 32 28 30
85 27 33 29 31
86 28 34 30 32
87 29 35 31 33
88 30 36 32 34
```

```
89 31 37 33 35
90 32 38 34 36
91 33 39 35 37
92 34 40 36 38
93 35 41 37 39
94 36 42 38 40
95 37 43 39 41
96 38 44 40 42
97 39 45 41 43
98 40 46 42 44
99 41 47 43 45
100    42 48 44 46
101    49 55 51 53
102    50 56 52 54
103    51 57 53 55
104    52 58 54 56
105    53 59 55 57
106    54 60 56 58
107    55 61 57 59
108    56 62 58 60
109    57 63 59 61
110    58 64 60 62
111    59 65 61 63
112    60 66 62 64
113    61 67 63 65
114    62 68 64 66
115    63 69 65 67
116    64 70 66 68
117    65 71 67 69
118    66 72 68 70
```

Appendix 2. Field Data Collection Forms

Wells	depth in m	casing length (m)	depth in ft	casing length (ft)
BM-04-34	61.0	13.7	200	45
BM-04-37	76.2	14.6	250	48
BM-04-38	76.2	13.7	250	45
BM-04-32	61.0	14.6	200	48

Well Pairs in order of priority:

34-37	Hottest boreholes
34-38	
37-38	
32-34	

DISTANCE MATRIX

Distance in meters

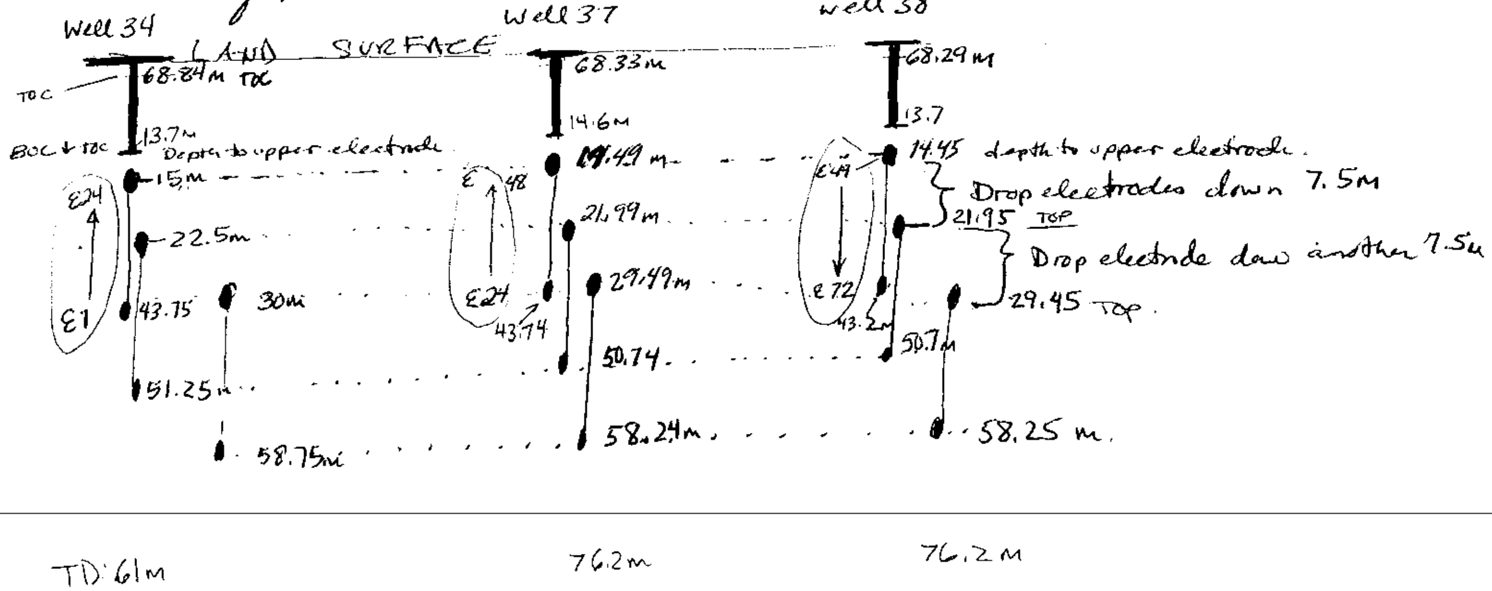
	BM-04-34	BM-04-37	BM-04-38	BM-04-32
BM-04-34	0	14.6	25.0	25.9
BM-04-37	48	0	15.2	~~25.0~~
BM-04-38	57	50	0	~~38.7~~
BM-04-32	85	~~82~~	~~127~~	0

Distance in ft

Bad electrode on cable BGAS1, 10th spot from machine on assigned arrays with electrodes 49-72
bad electrode at 58-59

Total length: (24-1)x 1.25m = 28.75m

3-D Configuration



Summary of ERT Surveys at Eastland Woolen Mill Superfund Site in Corrina, ME July 2007
Collected by Fred Day-Lewis and Carole Johnson
Using Syscal Pro, Auto switch 96 SN:18705-155445 957-95 (borrowed from Kamini Singha)
3 cables used: owned by BG, 1.25 m spacing, 24 steel electrodes each cable
See field notes for more details of survey layout.

Data filename in field	Wells in survey	Depth top electrode (m)	No of measure-ments	storage starting on block no.	Ending block	Date	start time	end time	comments
DipDip3d	(34, 37, 38)	15.0 m	1639	0	1639	7/9/07	12:35		
DipDip3d-recip	(34, 37, 38)	15.0 m	1639	1639	3278	7/9/07	13:35	15:45	
DipDip3d	(34, 37, 38)	22.5 m	1639	3278	4917	7/9/07	16:15		
DipDip3d-recip	(34, 37, 38)	22.5 m	1639	4917	6556	7/9/07	17:07	19:07	
DipDip3d	(34, 37, 38)	30.0 m	1639	6556	7101	7/10/07	8:40		survey stopped prematurely
DipDip3d	(34, 37, 38)	30.0 m	1639	7102	7648	7/10/07	9:00		second try - prematurely stopped
Fred3d.txt	(34, 37, 38)	30.0 m	1639	0	587	7/10/07	10:23		survey stopped prematurely
DipDip2d	(37, 38)	29.5 m	625	588		7/10/07	11:29		temporarily moved onto 2D surveys
DipDip3d-recip	(34, 37, 38)	30.0 m	1638	681	2319	7/10/07	11:55	13:50	
DipDip3d	(34, 37, 38)	30.0 m	1638	2320	3958	7/10/07	14:02	15:54	
Wenner3d	(34, 37, 38)	30.0 m	118	3959	4077	7/10/07	16:10		single channel collection
Wenner3d-recip	(34, 37, 38)	30.0 m	118	4077	4194	7/10/07	16:20		single channel collection
Wenner3d	(34, 37, 38)	22.5 m	118	4195	4312	7/10/07	16:51		single channel collection
Wenner3d-recip	(34, 37, 38)	22.5 m	118	4313	4430	7/10/07	17:03	17:12	single channel collection
Wenner3d	(34, 37, 38)	15.0 m	118	4431	4548	7/10/07	17:30	17:44	single channel collection
Wenner3d-recip	(34, 37, 38)	15.0 m	118	4549	4666	7/10/07	17:49	17:59	single channel collection
DipDip2d	(34, 32)	15.0 m	625	4667	5291	7/11/07	8:26	8:46	
DipDip2d-recip	(34, 32)	15.0 m	625	5292	5916	7/11/07	8:48	9:31	
DipDip2d	(34, 32)	22.5 m	625	5917	6541	7/11/07	10:35	10:55	
DipDip2d-recip	(34, 32)	22.5 m	625	6542	7166	7/11/07			
DipDip2d-recip	(34, 32)	30.0 m	625	7167	7791	7/11/07	11:55	12:45	
DipDip2d	(34, 32)	30.0 m	625	7792	8416	7/11/07	13:00	13:45	single channel collection
DipDip2d	(34, 32)	30.0 m	625	8417	9041	7/11/07	14:00	15:15	redo with 2X pulse duration (1s), single channel collection
DipDip2d-recip	(34, 32)	30.0 m	625	9042	9666	7/11/07	15:25	16:35	redo with 2X pulse duration (1s), single channel collection
DipDip2d	(34, 32)	30.0 m	625	9667	10291	7/12/07	8:27	9:03	redo with 1/2 the pulse duration (250 ms), 1 channel collection
DipDip2d-recip	(34, 32)	30.0 m	625	10292	10916	7/12/07	9:05	9:40	redo with 1/2 the pulse duration (250 ms), 1 channel collection
DipDip2d	(34, 32)	30.0 m	625	10917	11541	7/12/07	9:50	10:30	redo with 500us duration and 800 mV power
DipDip2d-recip	(34, 32)	30.0 m	625	11542	12166	7/12/07	10:40	11:30	redo with 500us duration and 800 mV power
DipDip2d	(34, 32)	22.5 m	625	12167	12791	7/12/07	12:34	12:58	with 10 channels and AC running
DipDip2d-recip	(34, 32)	22.5 m	625	12792	13416	7/12/07	13:00	13:51	with 10 channels and AC running
DipDip2d-recip	(34, 32)	15.0 m	625	13417	14041	7/12/07		14:53	with 10 channels and AC running
DipDip2d	(34, 32)	15.0 m	625	14042	14666	7/12/07	14:55	15:09	with 10 channels and AC running

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): Carole Johnson + Fred Day-Lewis
Datum:
Weather conditions: Cloudy, Drizzling, ~60°F
Date: 7/9/07

Measurement and system specifications:

Geometry filename: dipdip3d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro 18705-155445 997-95
Number of electrodes used: 24 x 3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 50mV

Electrode and well configuration: (note units)

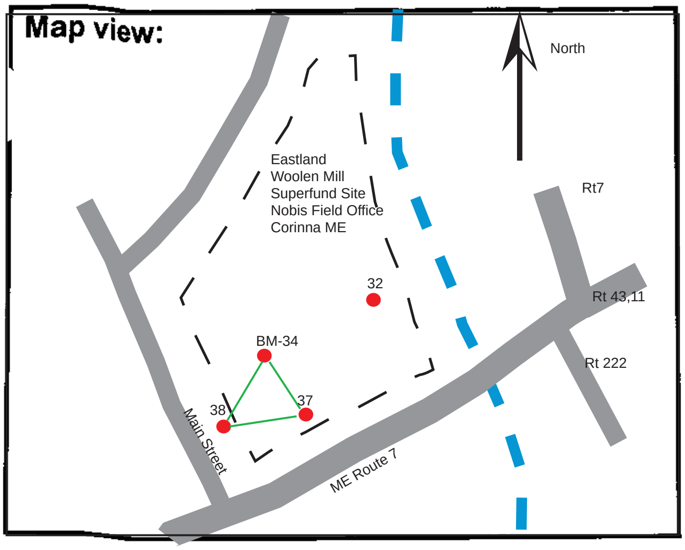
Well ID:	34	37	38		
Cable #:	MPT	BGAS 2	BGAS 1		
Electrodes (# – #):	1 - 24	25 - 48	49 - 72		
Elevation at TOC:	~~15.0m~~ 68.84	~~14.49~~ 68.33	68.29 ~~14.45~~		
6" casing Stickup:	~-10 cm	~-12cm	~-14cm		
Depth to upper electrode:	15m	14.49	14.45		
Electrode spacing:	1.25m	1.25m	1.25m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61m	76.2m	76.2m		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Stored at memory 0				

dipdip 3d txt

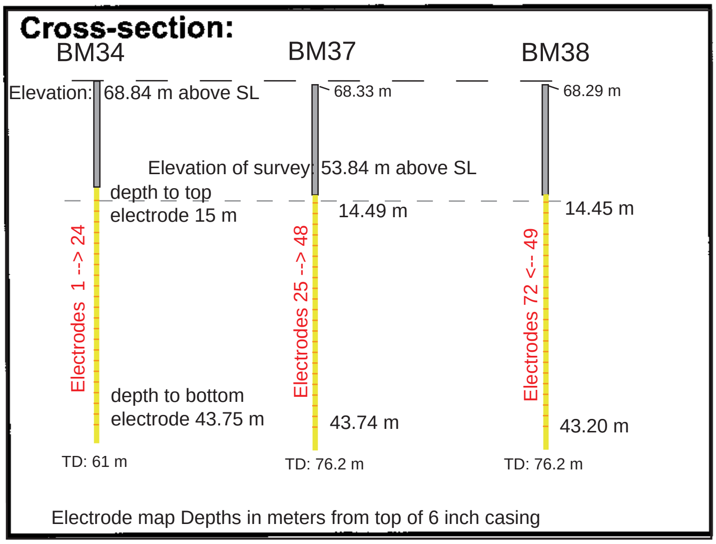
Top electrode at 15m in 34. **date:** 7/9/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 14.6 V Receiver battery level: 14.3V

Resistance check performed (check): ☒ Minimum value: 0.5 kΩ Maximum value: 2.00 kΩ

Pairs above 10 k-ohm: 58-59 (59 was 999.99 kΩ)

Survey start time: 12:35 pm

System checks at end of data collection:

Transmitter battery level: 13.6 V Receiver battery level: 13.3 V

Resistance check performed (check): ☐ Minimum value:______ Maximum value:______

Pairs above 10 k-ohm:______

Survey end time:______

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): Carole Johnson, Fred Day-Lewis
Datum:
Weather conditions: Raining, ~60° F
Date: 7/9/07

Measurement and system specifications:

Geometry filename: dipdip3drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro ~~189~~05-1557445997-95
Number of electrodes used: 24 x 3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 50 mV

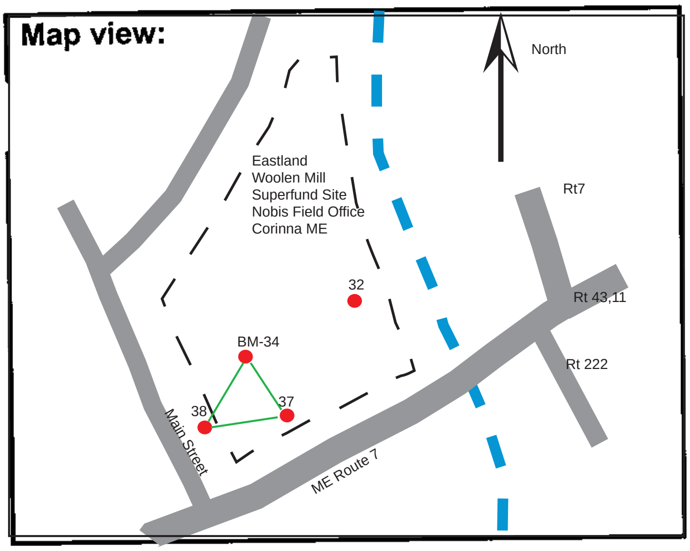
Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	MPT	BGAS 2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	~~15.0~~ 68.84 m	~~14.49~~ 68.33 m	~~14.45~~ 68.29 m		
Stickup:	~ -10cm	~ -12cm	~ -14cm		
Depth to upper electrode:	15.0m	14.49m	14.45m		
Electrode spacing:	1.25m	1.25m	1.25		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7	14.6	13.7		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61m	76.2m	76.2m		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Starting location in memory 1639				

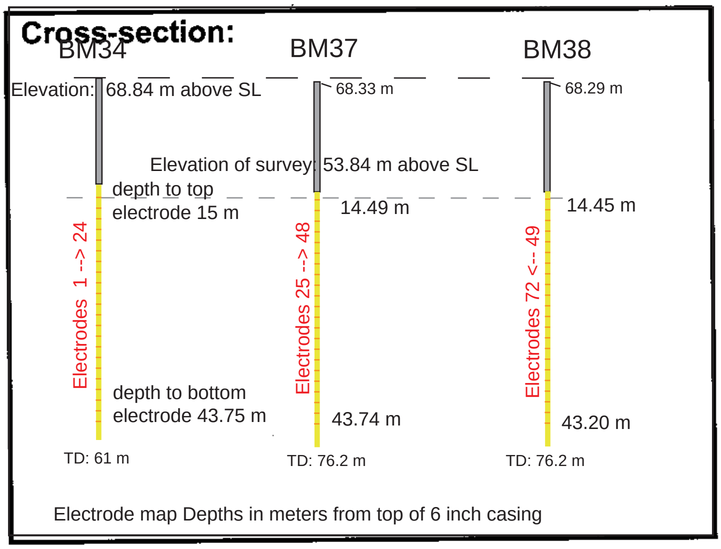
dip dip 3D reup
Top electrode in 34 @ 15m

date: 7/9/07

Site diagrams: (Label electrode number ranges for each well)



Map view:



Cross-section:

Electrode map Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6
Receiver battery level: 13.3
Resistance check performed (check): ☒
Minimum value: 0.43kΩ
Maximum value: 1.44kΩ
Pairs above 10 k-ohm: 58-59 (59 was +999 kΩ)
Survey start time: 13:35

System checks at end of data collection:

Transmitter battery level: 12.6
Receiver battery level: 13.3
Resistance check performed (check): ☐
Minimum value: 0.19
Maximum value: 2.01
Pairs above 10 k-ohm: 58-59 (59-60 999kΩ)
Survey end time: ~15:45

Data backup:

Data backed up (check): ☐
Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: ______ (units)
Operator(s): Carole Johnson, Fred Day-Lewis
Datum: ______
Weather conditions: Cloudy ~60°
Date: 7/19/07

Measurement and system specifications:

Geometry filename: d:pd:p3d.txt
Units (check one): ☒ meters ☐ feet
Data filename: ______
Iris unit model/SN: ______
Number of electrodes used: 24 x 3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☒
Injection pulse duration: 500mS
Voltage requested: 200mV

Electrode and well configuration: (note units)

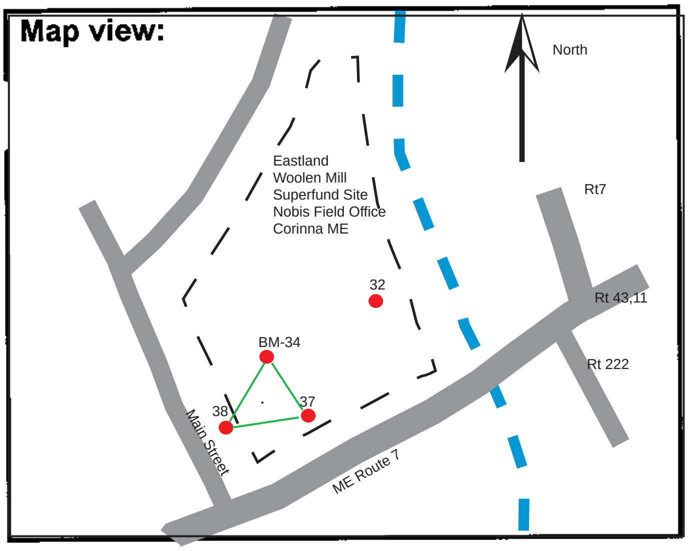
Well ID:	34	37	38		
Cable #:	MPT	BGAS2	BGAS1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC: 6" casing	68.84m	68.33m	68.29m		
Stickup:	~ -10cm	~ -12cm	~ -14cm		
Depth to upper electrode:	22.5m	21.99 m	21.95m		
Electrode spacing:	1.25mm	1.25m	1.25m		
Electrode type:	steel	Steel	Steel.		
Length of casing:	13.7m	14.6m	15.7		
Type of casing:	steel	Steel	Steel		
Sounded well depth:	61m	76.2m	76.2m		
Screened intervals:	—	—	—		
Depth to water:	2.13m @17:45	1.75m @17:45	1.70m @17:47		
Notes:	Start @ location 3278 in memory				

DipDip3D.txt with
top electrode at 22.5
in 34.

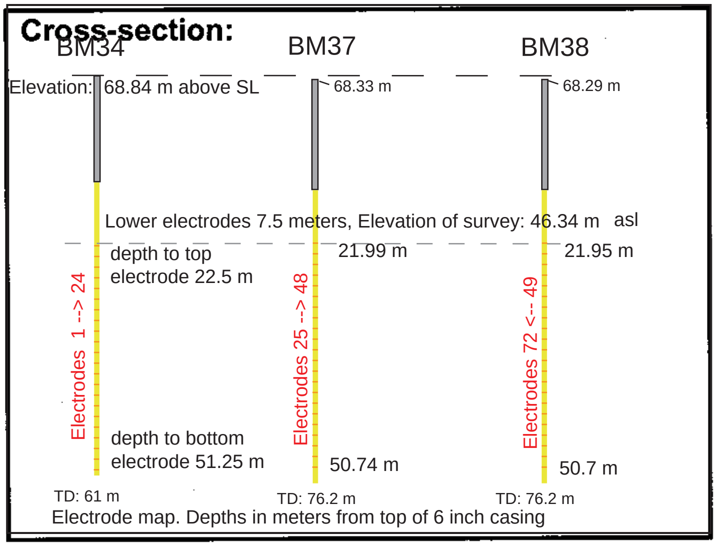
date: 7/19/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.3 Receiver battery level: 13.6

Resistance check performed (check): ☒ Minimum value: 0.19 Maximum value: ~~767~~ 2.01

Pairs above 10 k-ohm: 58-59 (59-60 999 kΩ)

Survey start time: 16:15

System checks at end of data collection:

Transmitter battery level: 13.4 ✓ Receiver battery level: 13.3 ✓

Resistance check performed (check): ☐ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm:________

Survey end time:________

Data backup:

Data backed up (check): ☐ Location:________

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, Maine
GPS location: (units)
Operator(s): Fred Day Lewis, Carole
Datum:
Weather conditions: rainy, cool, 60°F
Date: 7/9/07

Measurement and system specifications:

Geometry filename: dipdip3D ~~ramp~~.txt.
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: SyscalPro 18705-15544599795
Number of electrodes used: 24 x 3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0 %
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 200 mV

Electrode and well configuration: (note units)

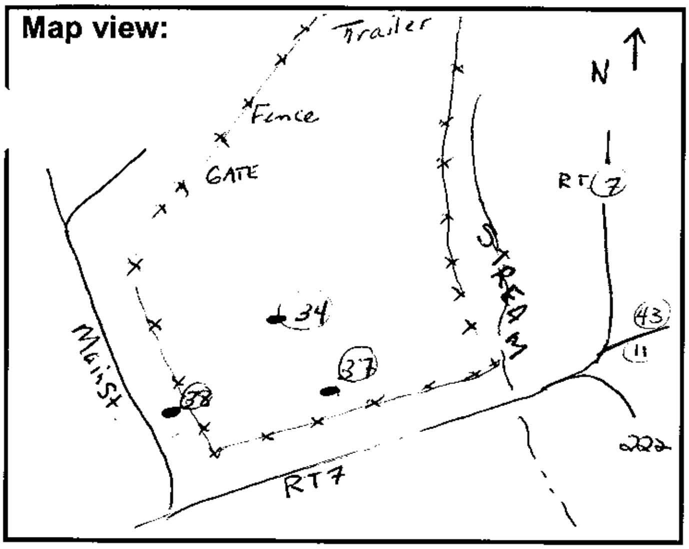
Well ID:	34	37	38		
Cable #:	MPT	BGAS-2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC: 6"	68.84 m	68.33 m	68.29 m		
Stickup:	~ -10 cm	~ -12 cm	~ -14 cm		
Depth to upper electrode:	22.5	21.99	21.95		
Electrode spacing:	1.25 m	1.25 m	1.25 m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61 m	76.2 m	76.2 m		
Screened intervals:	–	–	–		
Depth to water: From 6" TOC	2.13 m @ 5:47	1.75 m at 547	1.70 m @ 547		
Notes:	Memory block 4917				

dip dip 3D recip
"Dropped cable down 7.5m" to 22.5m in 34.

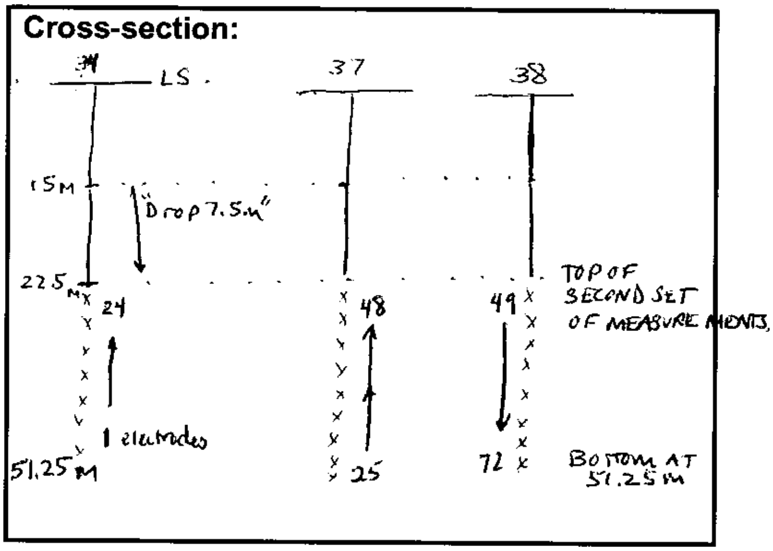
date: 7/9/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Well offsets: units_______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.4 Receiver battery level: 13.3

Resistance check performed (check): ☑ Minimum value: 0.19 Maximum value: 2.4

Pairs above 10 k-ohm: 58-59

Survey start time: 17:07

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.3

Resistance check performed (check): ☒ Minimum value: 0.19 Maximum value: 2.4

Pairs above 10 k-ohm: 58-59

Survey end time: 19:07

Data backup:

Data backed up (check): ☐ Location:

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy, ~60°F
Date: 7/10/07

Measurement and system specifications:

Geometry filename: dpdip3d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro 18705 15544S 99795
Number of electrodes used: 24 x 3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☒
Injection pulse duration: 500mS
Voltage requested: 200mV

Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	MPT	BGAS2	BGAS1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC: 6" casing	68.84m	68.33m	68.29m		
Stickup:	~ -10cm	~ -12cm	~ -14cm		
Depth to upper electrode:	30m ~~22.5m~~	24.99m	21.95m		
Electrode spacing:	1.25m	1.25m	1.25m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7m	14.6	13.7		
Type of casing:	Steel	Steel	Steel.		
Sounded well depth:	61m	76.2m	76.2m.		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Started at memory 6556				

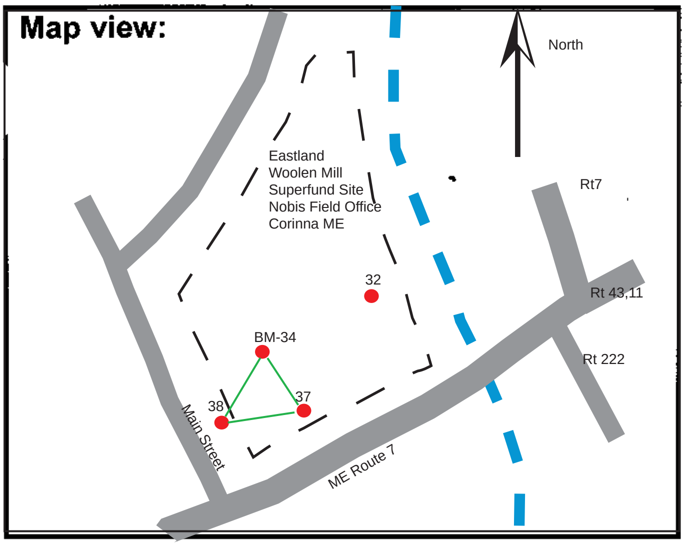
(Should have gone to 8195)

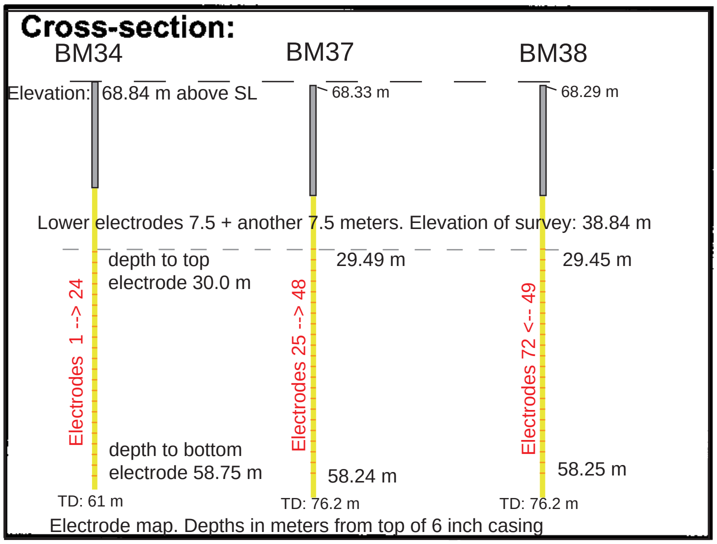
Survey stopped prematurely with errors. Data saved through block 7101. ∴ Went to 546, which is the first ~~and the~~ Dipol D measurements only

dropped cable in
well 34 to 30m
from TOC to 1st electrode

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 14.5 ✓ Receiver battery level: 14.2 ✓

Resistance check performed (check): ☒ Minimum value: 0.19 Maximum value: 240

Pairs above 10 k-ohm: 58-59 (59 999 kΩ)

Survey start time: 8:40

System checks at end of data collection:

Transmitter battery level:______ Receiver battery level:______

Resistance check performed (check): ☐ Minimum value:______ Maximum value:______

Pairs above 10 k-ohm:______

Survey end time:______

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum:
Weather conditions: Cloudy, 60°F
Date: 7/10/07

Measurement and system specifications:

SECOND TRY FOR THIS CONFIGURATION/SETUP

Geometry filename: dipdip3d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: SysalPro 1870S 155445 99795
Number of electrodes used: 24 x 3
Number of quadripoles:
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☒
Injection pulse duration: 500mS
Voltage requested: 200mV

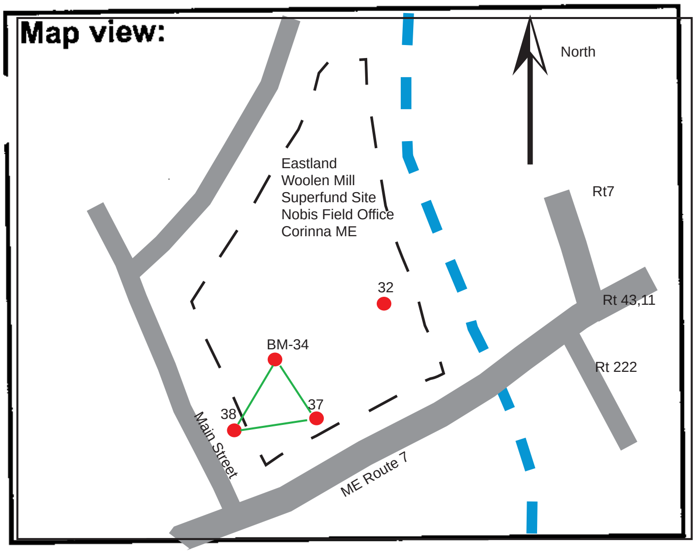
Electrode and well configuration: (note units)

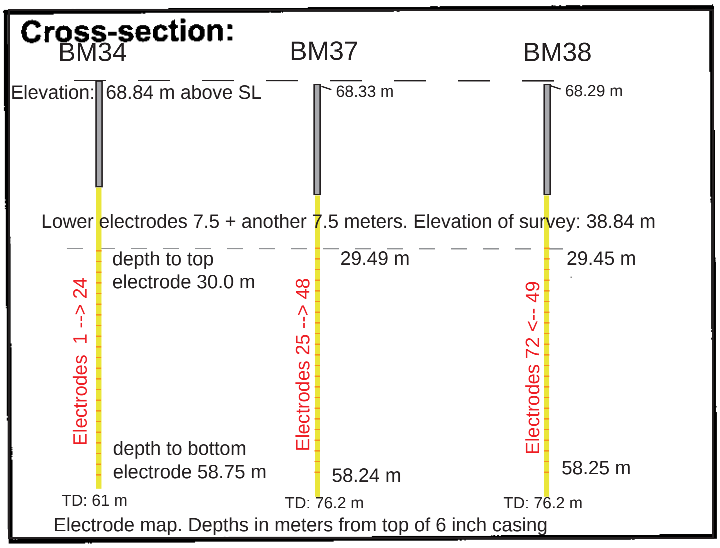
Well ID:	34	37	38		
Cable #:	MPT	BGAS 2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	68.84m	68.33m	68.29cm		
Stickup:	~ -10cm	~-12cm	~ -14cm		
Depth to upper electrode:	30m	29.49m	29.45m		
Electrode spacing:	1.25m	1.25m	1.25m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7m	14.6 m	13.7m		
Type of casing:	Steel	Steel	Steel.		
Sounded well depth:	61	76.2m	76.2m		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Started at memory block 7102				

prematurely stopped at end of first panel at 546th measurement dipdip38.txt Second try for this.

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.4 Receiver battery level: 13.6

Resistance check performed (check): ☒ Minimum value: 0.19 Maximum value: 298kΩ

Pairs above 10 k-ohm: 58-59 (59 was 999kΩ)

Survey start time: 9:00

System checks at end of data collection:

Transmitter battery level:______ Receiver battery level:______

Resistance check performed (check): ☐ Minimum value:______ Maximum value:______

Pairs above 10 k-ohm:______

Survey end time:______

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): F DayLewis, C. Johnson
Datum:
Weather conditions: overcast, cool, humid
Date: 7/10/07

Measurement and system specifications: Redo

Geometry filename: Fred3D.txt
Units (check one): ☑ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro 18705-155445 997 95
Number of electrodes used: 24x3
Number of quadripoles: 1639
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0 %
Reciprocal data?: ☑
Injection pulse duration: 500 mS
Voltage requested: 50 mV

Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	1-24	25-48	49-72		
Electrodes (# – #):	MPT	BGAS 2	BGAS 1		
Elevation at TOC:	68.84	68.33	68.29		
Stickup:	-10 cm	-12 cm	-14 cm		
Depth to upper electrode:	30 m	29.49	29.45		
Electrode spacing:	1.25 m	1.25 m	1.25 m.		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61.0 m	76.2 m	76.2 m		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Start on black 0				

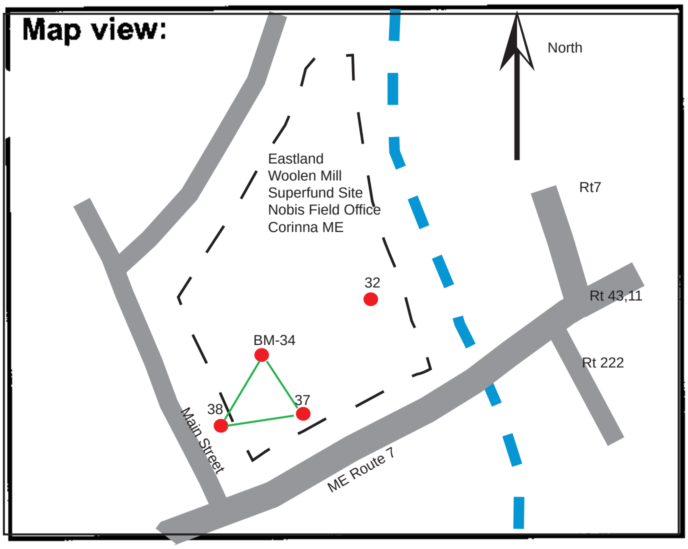
Stopped on measurement 587

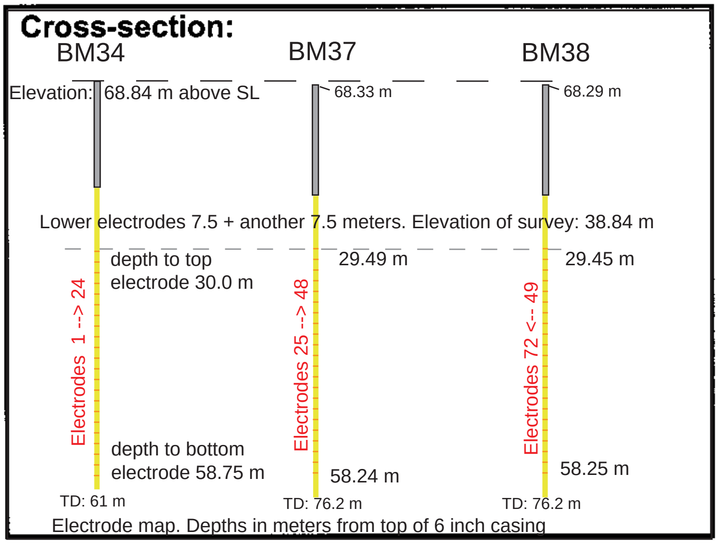
Redo of Dip Dip 3D with top electrode at 30m.

FRED 3D .txt

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.3 Receiver battery level: 13.6

Resistance check performed (check): ☑ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm: 58-59

Survey start time: 10:23

System checks at end of data collection:

Transmitter battery level:________________ Receiver battery level:________________

Resistance check performed (check): ☐ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm:________________________________

Survey end time:________________

Data backup:

Data backed up (check): ☐ Location:________________________________

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: ____ (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum: ____
Weather conditions: ____
Date: 7/10/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☐ meters ☐ feet
Data filename: ____
Iris unit model/SN: ____
Number of electrodes used: ____
Number of quadripoles: 625
Number of stacks minimum/maximum: ____ / ____
Voltage (check one): ☐ signed ☐ unsigned
Requested standard deviation: ____
Reciprocal data?: ☒ included in file
Injection pulse duration: ____
Voltage requested: ____

Electrode and well configuration: (note units)

Well ID:	37	38			
Cable #:	2	1			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.33 m	68.29 m			
Stickup:	-12 cm	-14 cm			
Depth to upper electrode:	29.49	29.45			
Electrode spacing:	1.25	1.25			
Electrode type:	Steel	Steel			
Length of casing:	14.6	13.7			
Type of casing:	Steel	Steel			
Sounded well depth:	76.2 m	76.2 m			
Screened intervals:	—	—			
Depth to water:					
Notes: Start on memory block.	588				

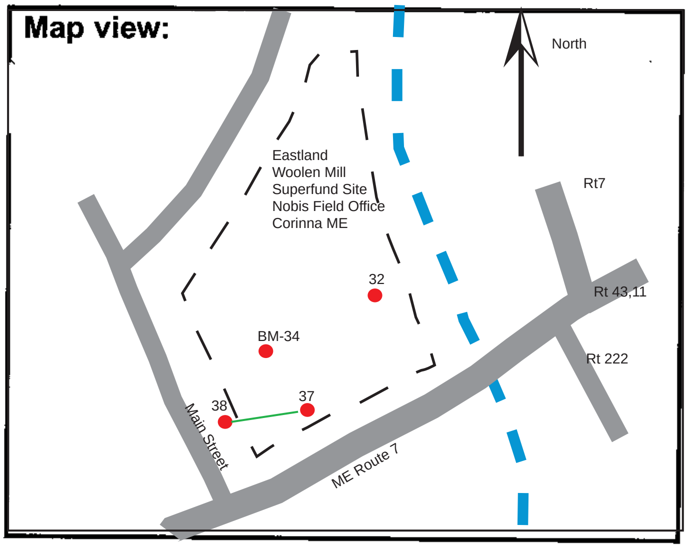
dip dip 2D

Top electrode @ 29.49

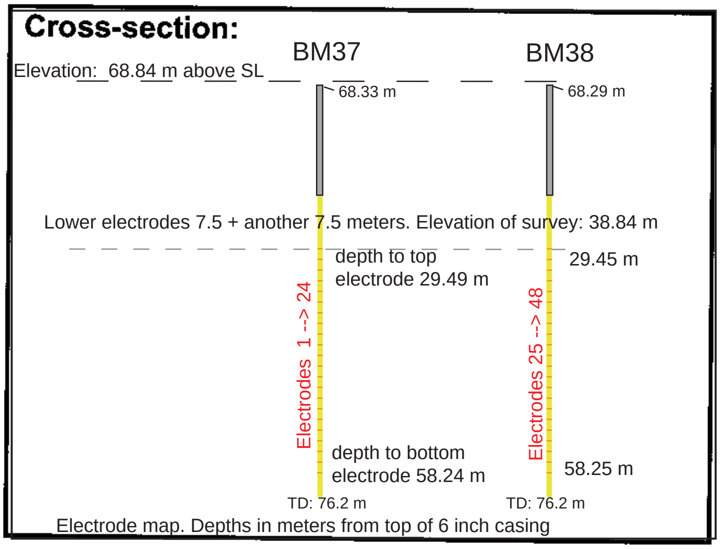
date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 12.6 Receiver battery level: 12.3

Resistance check performed (check): ☒ Minimum value: 0.16 Maximum value: 2

Pairs above 10 k-ohm: 37-38 999kΩ

Survey start time: 11:29

System checks at end of data collection:

Transmitter battery level: 12.6 v Receiver battery level: 12.3 v

78%

Resistance check performed (check): ☑ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm:________________________

Survey end time:________________

Data backup:

Data backed up (check): ☐ Location:________________________

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USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): F. Day Lewis / C. Johnson.
Datum:
Weather conditions: Sunny warm
Date: 7/10/07

Measurement and system specifications:

Geometry filename: DipDip 3D. recip. txt
Units (check one): ☑ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro
Number of electrodes used: 24X3
Number of quadripoles: 1638
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0 %
Reciprocal data?: ☑
Injection pulse duration: 500 mS
Voltage requested: 50 mV

Electrode and well configuration: (note units)

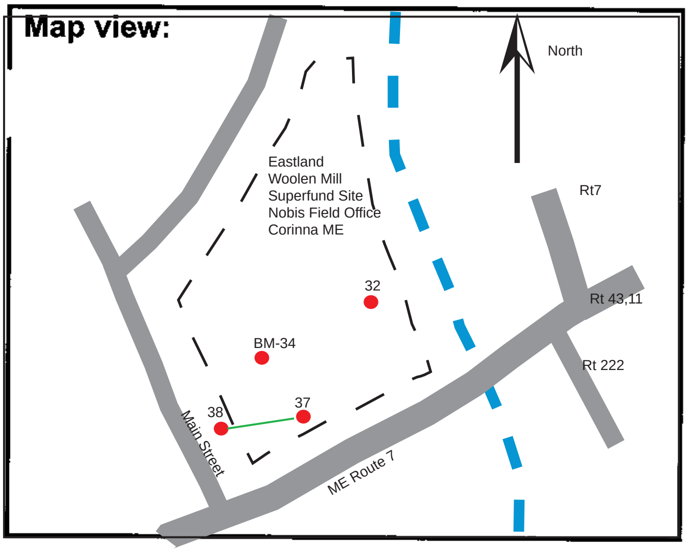
Well ID:	34	37	38		
Cable #:	MPr	BGAS 2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	~ -10 cm	~ -12 cm	~ 14 cm		
Stickup:	68.84 m↑SL	68.33 m	68.29 m		
Depth to upper electrode:	30 m	29.49 m	29.45 m		
Electrode spacing:	1.25 m	1.25 m	1.25 m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel.		
Sounded well depth:	61.0 m	76.2 m	76.2 m		
Screened intervals:					
Depth to water:					
Notes:	Store data from 681				

DipDip3D recip. with top electrode is at 30m in 34

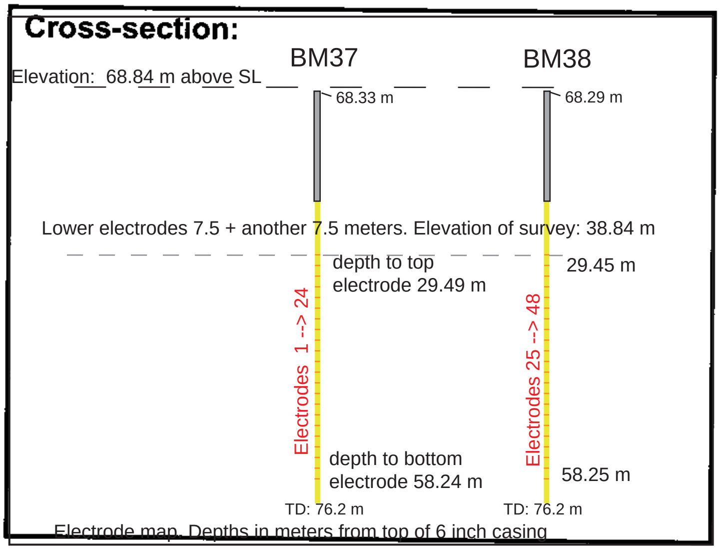
date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 12.6 Receiver battery level: 12.3

Resistance check performed (check): ☑ Minimum value: .19 Maximum value:______

Pairs above 10 k-ohm: 58-59 999 Ω

Survey start time: 11:55

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☐ Minimum value: ~0.16 Maximum value: ~1.0

Pairs above 10 k-ohm: 58 - 59 999.49 ohm

Survey end time: ~13:50

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): F. Day-Lewis / C. Johnson
Datum:
Weather conditions: Sunny
Date: July 10, 2007

Measurement and system specifications:

Geometry filename: Dip Dip 3D.
Units (check one): ☑ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro
Number of electrodes used: 24 X 3
Number of quadripoles: 1638
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☑
Injection pulse duration: 500 ms
Voltage requested: 50 mV

Single channel measurements

Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	MPT	BGAS2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	68.8 m	68.3 m	68.3 m		
Stickup:	~-10 cm	~-12 cm	~ -14 cm		
Depth to upper electrode:	30 m.	29.49 m	29.45 m		
Electrode spacing:	1.25 m.	1.25 m	1.25 m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61 m	76.2 m	76.2 m.		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Stored at Mem block 2320				

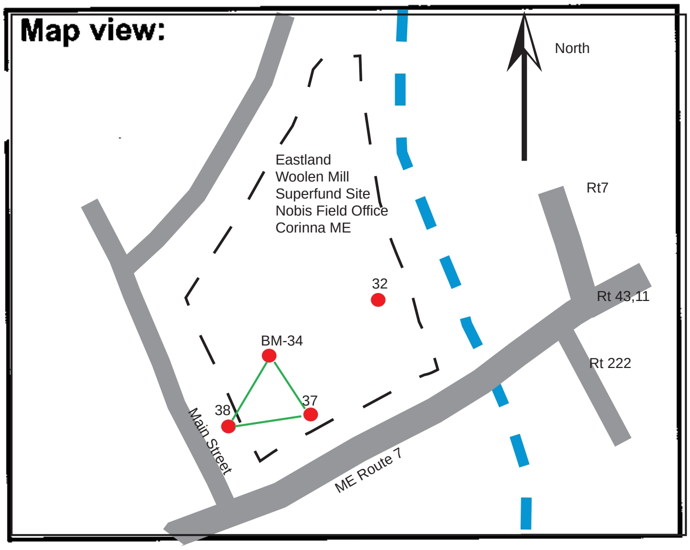
1638

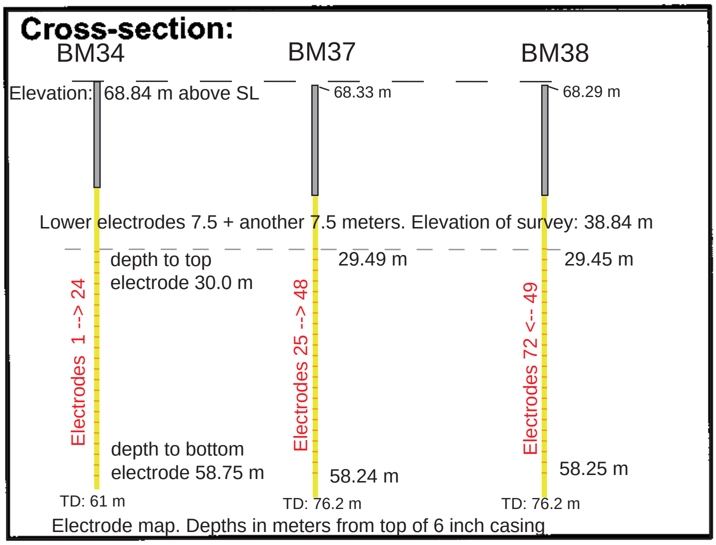
~ 14:05

Dip Dp 3D try at ~14:05.
with top electrode at 30m in well 34

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)


Map view:


Cross-section:

Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6v Receiver battery level: 13.4v

Resistance check performed (check): ☑ Minimum value: ~.16 Maximum value: ~1.0

Pairs above 10 k-ohm: 58-59 electrodes

Survey start time: 14:02

System checks at end of data collection:

Transmitter battery level: 13.6v Receiver battery level: 13.4v

Resistance check performed (check): ☐ Minimum value: 0.14 Maximum value: ~1.

Pairs above 10 k-ohm: 58-59 electrodes

Survey end time: 15:54

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, Maine
GPS location: ______ (units)
Operator(s): F. Day Lewis, C. Johnson
Datum: ______
Weather conditions: Sunny, Warm
Date: 07/10/07

Measurement and system specifications:

Geometry filename: wenner 3d.txt
Units (check one): ☒ meters ☐ feet
Data filename: ______
Iris unit model/SN: Syscal Pro 18705 155445 99795
Number of electrodes used: 24 X 3
Number of quadripoles: 118
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0 %
Reciprocal data?: ☑
Injection pulse duration: 500 mS
Voltage requested: 50 mV

Single Channel measurements

Electrode and well configuration: (note units)

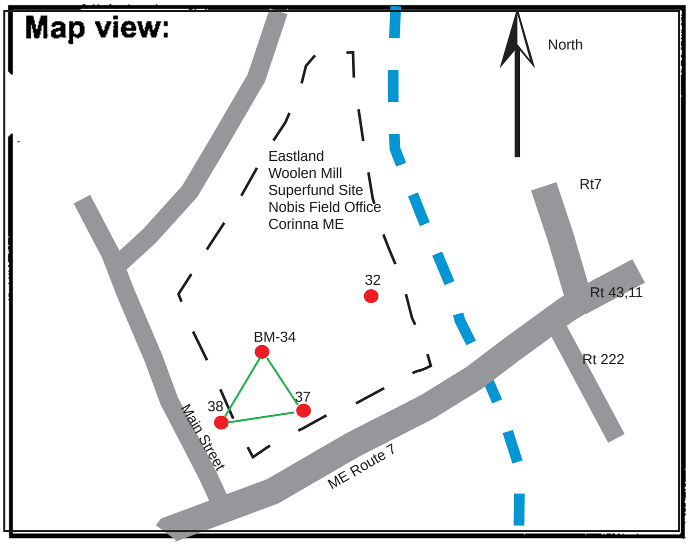
Well ID:	34	37	38		
Cable #:	MPT	BGAS2	BGAS1		
Electrodes (# – #):	1-24	25-48	49-72.		
Elevation at TOC:	68.84m	68.33m	68.29		
Stickup:	~ -10 cm	~ -12cm	~ -14cm		
Depth to upper electrode:	30m	29.49	29.45		
Electrode spacing:	1.25 m	1.25m	1.25m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7m	14.6 m	13.7m		
Type of casing:	Steel	Steel	Steel		
Sounded well depth:	61m	76.2m	76.2m		
Screened intervals:	–	–	–		
Depth to water:	Start				
Notes:	Stream mem block: 3958				

Wenner 3d
top electrode at 30m

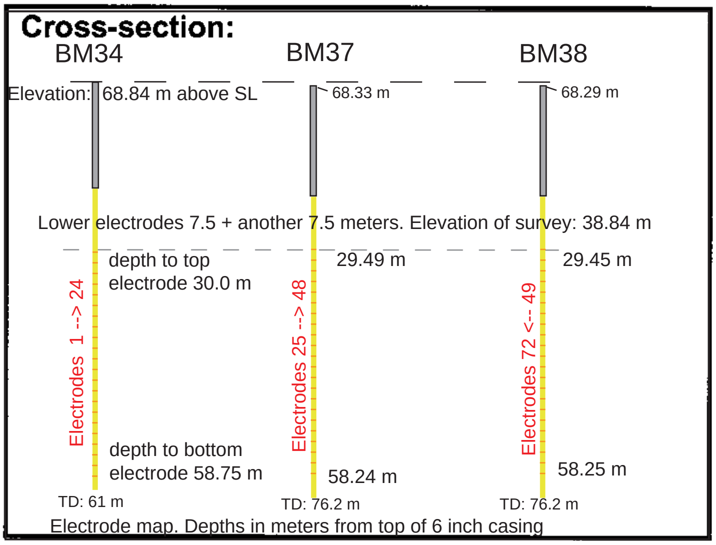
date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 v Receiver battery level: 13.4v

Resistance check performed (check): ☑ @16:10 Minimum value: .12 Maximum value: 1.84

Pairs above 10 k-ohm: 58-59.

Survey start time: @ 16:10

System checks at end of data collection:

Transmitter battery level: 13.6 ✓ Receiver battery level: 13.4v

Resistance check performed (check): ☐ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm:________

Survey end time:________

Data backup:

Data backed up (check): ☐ Location:________

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name:
GPS location: (units)
Operator(s): F. Day-Lewis / C. Johnson
Datum:
Weather conditions: Sunny Warm
Date: July 10, 2007

Measurement and system specifications:

Geometry filename: Wenner 2D recip.
Units (check one): ☐ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x3
Number of quadripoles: 118
Number of stacks minimum/maximum: 2/3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☑
Injection pulse duration: 500 ms
1 Channel collection
Voltage requested: 50 mV

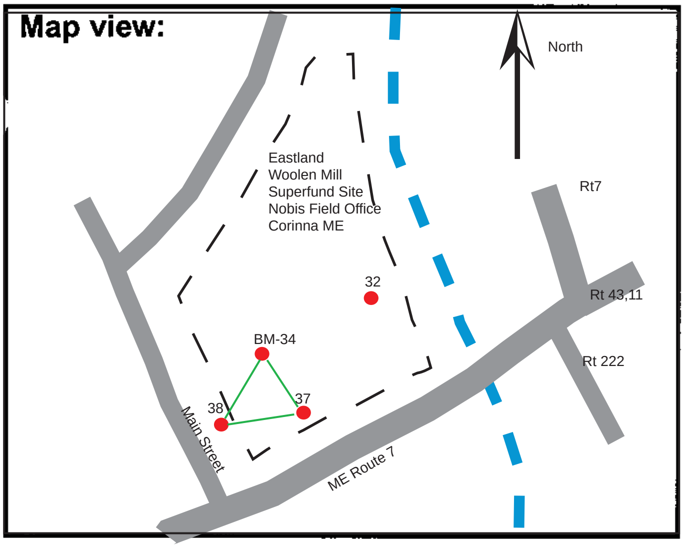
Electrode and well configuration: (note units)

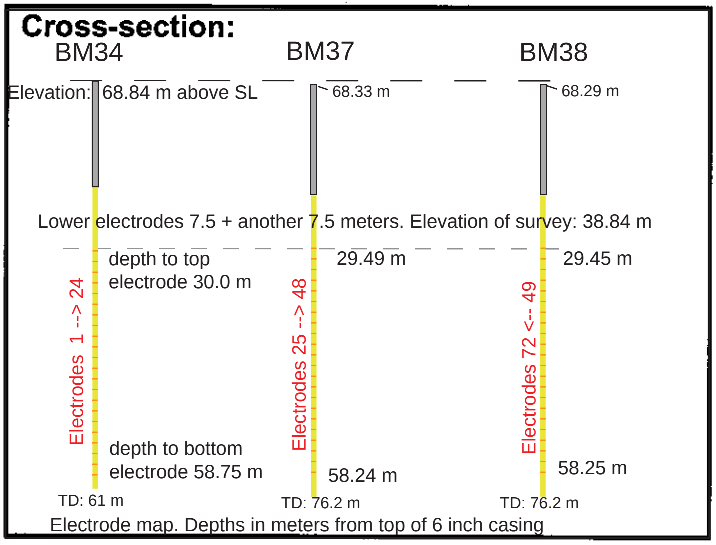
Well ID:	34	37	38		
Cable #:	MPT	Bgas 2	Bgas 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	68.84m	68.33m	68.29m		
Stickup:	~16 cm	~12cm	~14cm		
Depth to upper electrode:	30m	29.49m	29.45m		
Electrode spacing:	1.25 m	1.25 m	1.25m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel.		
Sounded well depth:	61 m	76.2m	76.2m		
Screened intervals:	—	—	—		
Depth to water:					
Notes: Start storage on block	4077				

Werner
~~dip dip~~ 3D recip.

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 ✓ Receiver battery level: 13.4 ✓

Resistance check performed (check): ☑ Minimum value: 0.11 Maximum value: 1.88 at 58 & 59.

↳ always early in the collection

Pairs above 10 k-ohm:

Survey start time: 16:20

System checks at end of data collection:

Transmitter battery level:______ Receiver battery level:______

Resistance check performed (check): ☐ Minimum value:______ Maximum value:______

Pairs above 10 k-ohm:______

Survey end time:______

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna Maine

GPS location: (units)

Operator(s): F Day Lewis / C. Johnson

Datum:

Weather conditions: Sunny Warm

Date: July 10, 2007

Measurement and system specifications:

Geometry filename: Wenner 3D

Units (check one): ☑ meters ☐ feet

Data filename:

Iris unit model/SN:

Number of electrodes used: 24x3

Number of quadripoles: 118

Number of stacks minimum/maximum: 2 / 3

Voltage (check one): ☑ signed ☐ unsigned

Requested standard deviation: 2.0%

Reciprocal data?: ☑

Injection pulse duration: 500 ms

Voltage requested: 50 mv

Single Channel

Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	MPT	Byoo 2	Byoo1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:	68.84 m	68.33 m	68.29 m		
Stickup:	~-10 cm	~ -12 cm	~ -14 cm		
Depth to upper electrode:	22.5	21.99	21.95		
Electrode spacing:	1.25 m	1.25 m	1.25 m		
Electrode type:	Steel	Steel	Steel		
Length of casing:	13.7 m	14.6 m	13.7 m		
Type of casing:	Steel	Steel	Steel.		
Sounded well depth:	61 m	76.2 m	76.2 m		
Screened intervals:	—	—	—		
Depth to water:					
Notes:	Start mem block at 4195				

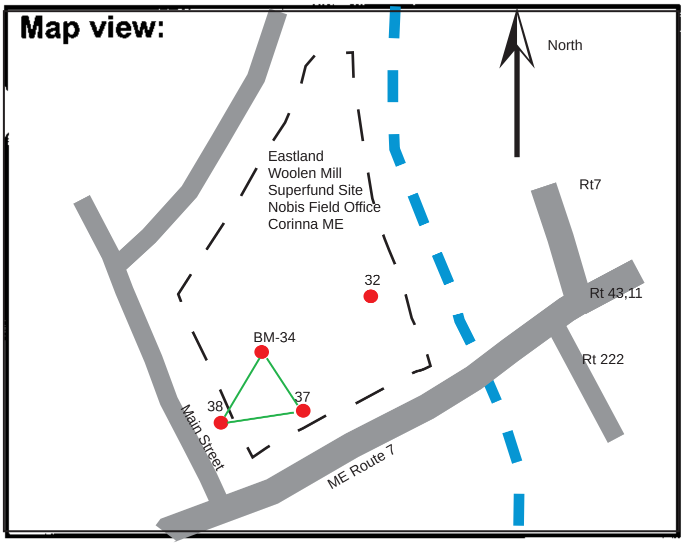
Wenner 36

22.5 'top.

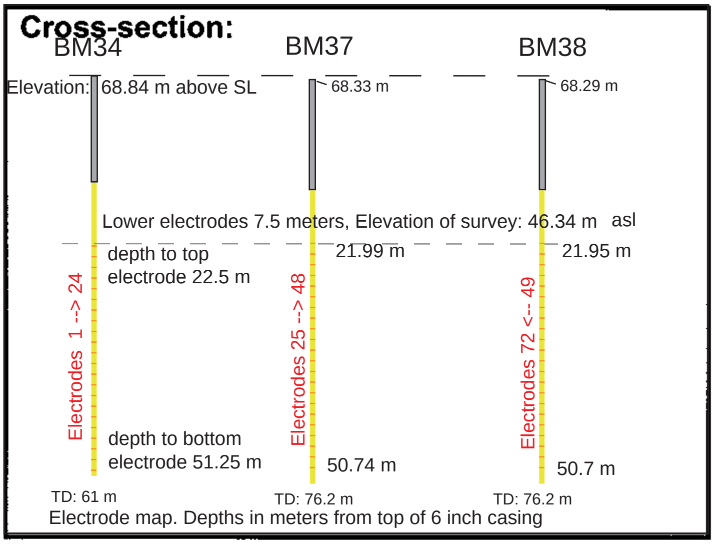
date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 V Receiver battery level: 13.4 V

Resistance check performed (check): ☑ Minimum value: .13 Maximum value: 1.8 @ 58-59.

Pairs above 10 k-ohm:______

Survey start time: 1651

System checks at end of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☑ Minimum value: 0.17 Maximum value: 1.7

Pairs above 10 k-ohm: 59 was 999kΩ

Survey end time:______

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna Maine
GPS location: (units)
Operator(s): F. Day Lewis / C. Johnson
Datum:
Weather conditions: Sunny, warm
Date: July 7, 2007

Measurement and system specifications:

Geometry filename: Wenner 3D recip.
Units (check one): ☑ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 X 3
Number of quadripoles: 118
Number of stacks minimum/maximum: 2/3
Voltage (check one): ☑ signed ☐ unsigned
Requested standard deviation: 2.0%
Reciprocal data?: ☑
Injection pulse duration: 500 ms
Voltage requested: 50 mV

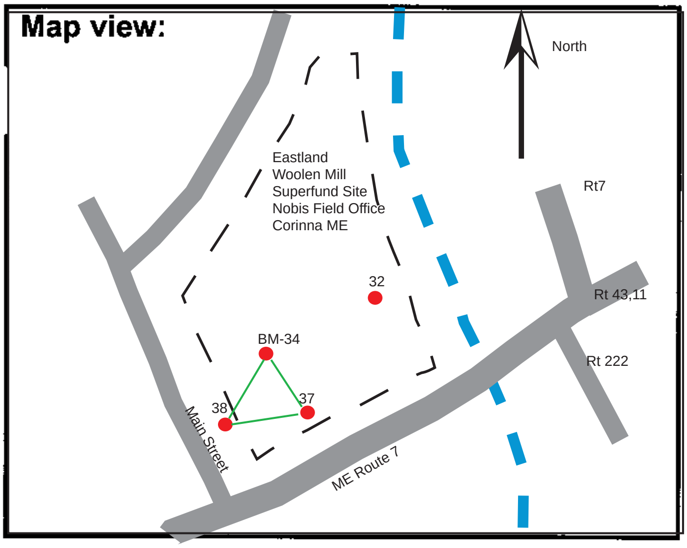
Electrode and well configuration: (note units)

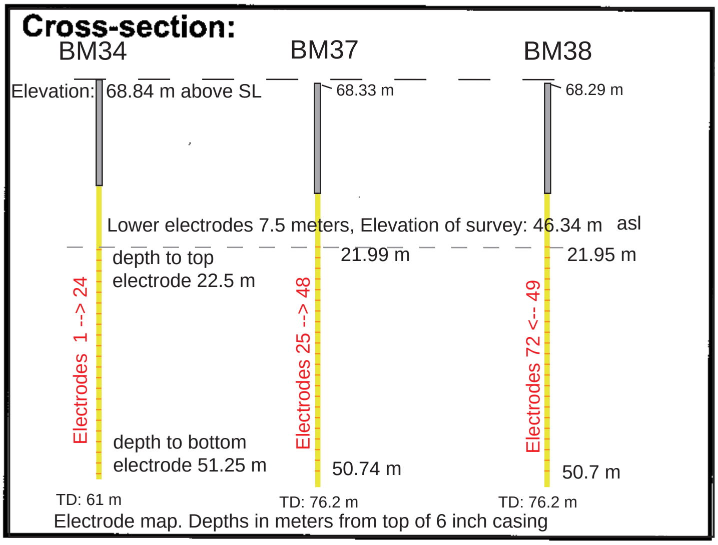
Well ID:	34	37	38		
Cable #:	1-24	25-48	49-72		
Electrodes (# – #):					
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	22.5m	21.99	21.95		
Electrode spacing:	1.25 m	1.25m	1.25 m		
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	4313				

Werner 3D recip.
Top electrode at 22.5 m
in well 34.

date: July 10, 2007

Site diagrams: (Label electrode number ranges for each well)


Map view:


Cross-section:

Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☒ Minimum value: 0.17 Maximum value: 1.7

Pairs above 10 k-ohm: 59 was 999 kΩ

Survey start time: 17:03

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☐ Minimum value: 0.17 Maximum value: 1.8

Pairs above 10 k-ohm:______

Survey end time: 17:12

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum:
Weather conditions: Sunny ~80°F
Date: 7/10/07

Measurement and system specifications:

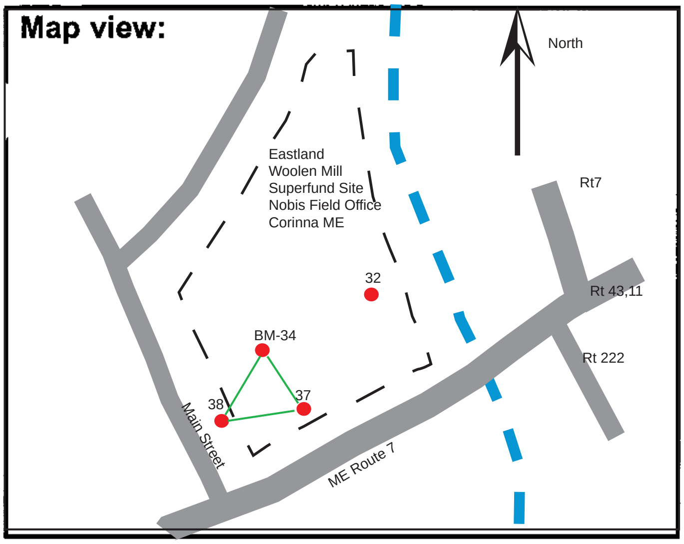
Geometry filename: wenner3d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 X 3
Number of quadripoles: 118
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 50 mV

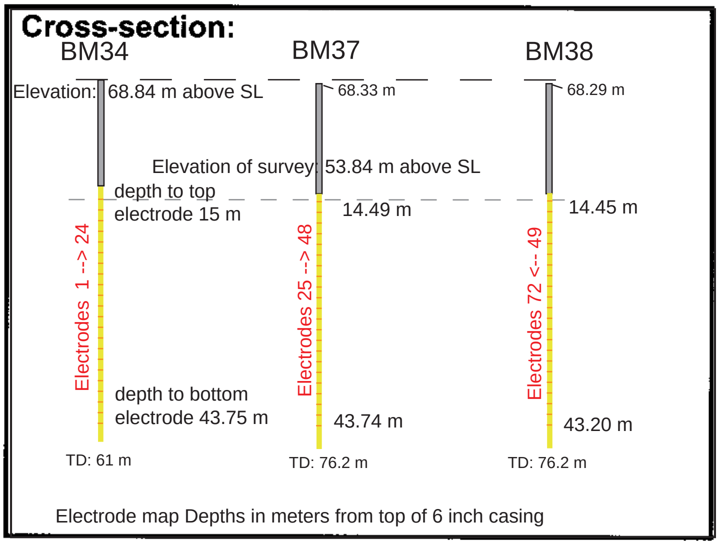
Electrode and well configuration: (note units)

Well ID:	34	37	38		
Cable #:	MPT	BGAS 2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72.		
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	~~30m~~ 15m	14.49	14.45		
Electrode spacing:					
Electrode type:	Steel	Steel	Steel		
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	4431				

wenner 3d.txt w/
top electrode at 15m in well 34 date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units_______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.17 Maximum value: 1.8

Pairs above 10 k-ohm: 59 was 999 kΩ

Survey start time: 17:30

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.29 Maximum value: 1.5

Pairs above 10 k-ohm: 59 was 999 kΩ

Survey end time: 17:44

Data backup:

Data backed up (check): ☐ Location:__________

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum:
Weather conditions: Sunny ~80°F
Date: 7/10/07

Measurement and system specifications:

Geometry filename: wenner3drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 3
Number of quadripoles: 118
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500mS
Voltage requested: 50mV

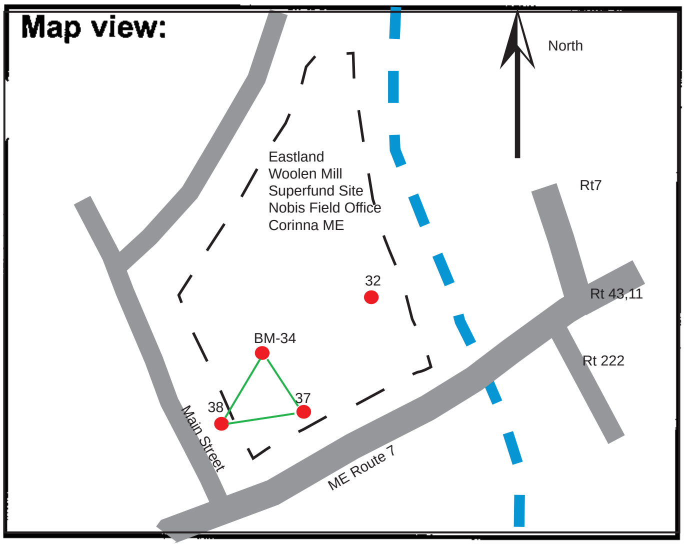
Electrode and well configuration: (note units)

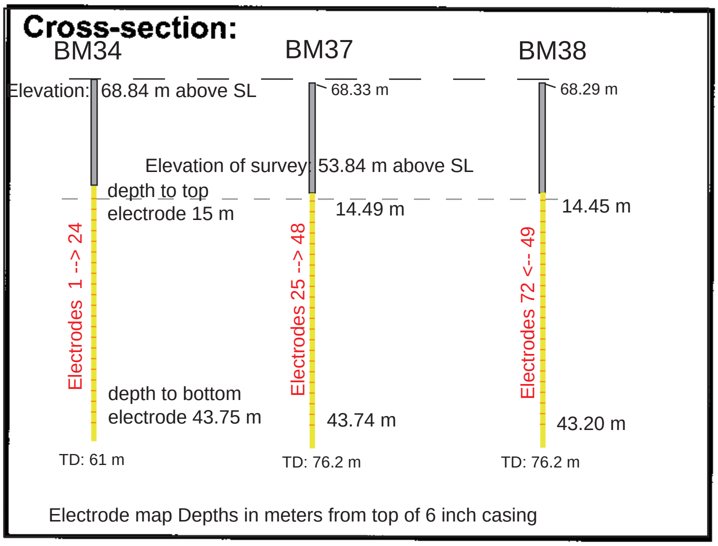
Well ID:	34	37	38		
Cable #:	MPT	BGAS 2	BGAS 1		
Electrodes (# – #):	1-24	25-48	49-72		
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	15m				
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	4549				

wenner 3d reciprocals
w/ depth to 1st electrode
of 15m in well 34

date: 7/10/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: ~~13.4~~ 13.6 Receiver battery level: ~~13.6~~ 13.4

Resistance check performed (check): ☒ Minimum value: 0.29 Maximum value: 1.5

Pairs above 10 k-ohm: 59 was 999kΩ

Survey start time: 17:49

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.29 Maximum value: 1.5

Pairs above 10 k-ohm: 59 was 999 kΩ

Survey end time: 17:59

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C JOHNSON, F.DAY-LEWIS
Datum:
Weather conditions: Drizzling ~65° F
Date: ~~7/10~~ 7/11/07

Measurement and system specifications:

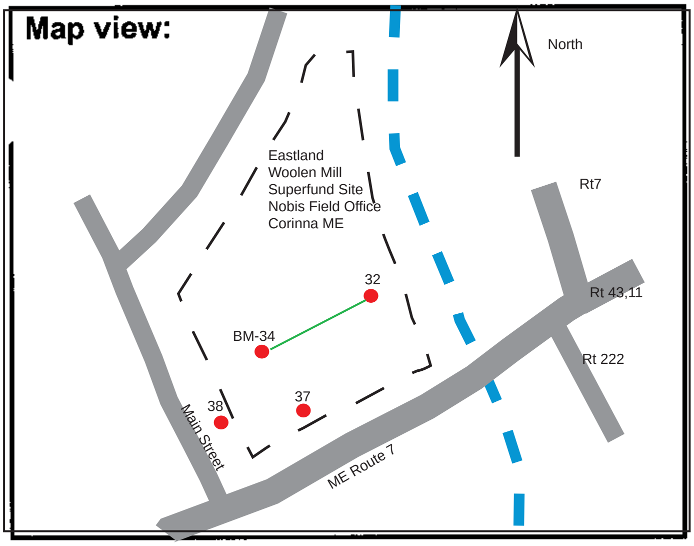
Geometry filename: ~~well~~ dipdip 2d
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN: Syscal Pro Switch 96 18705-
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 50mV

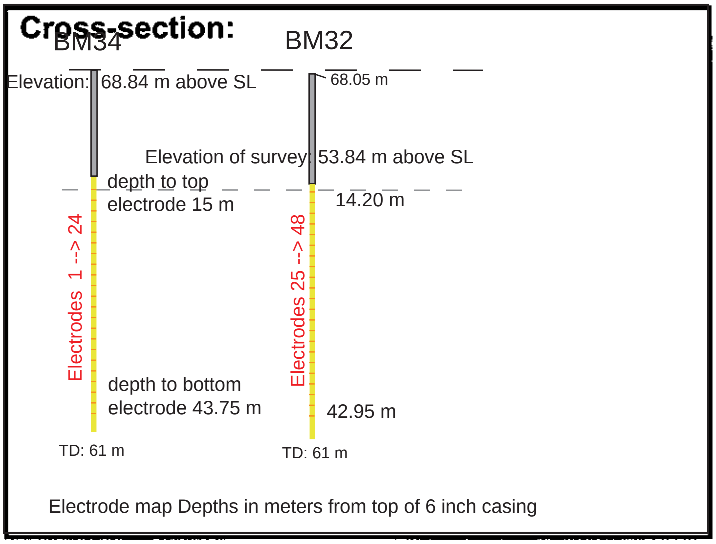
Electrode and well configuration: (note units)

Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84	68.05			
Stickup:	-10 cm	- 12.2 cm			
Depth to upper electrode:	15m	14.20			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:	13.7m	14.6m			
Type of casing:	Steel	Steel			
Sounded well depth:					
Screened intervals:	—	—			
Depth to water:					
Notes:	4667				

dip dip 2d w/ Top electrode at 15m in well 34 date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.5 V Receiver battery level: 13.3V

Resistance check performed (check): ☒ Minimum value: 0.54 Maximum value: 1.9

Pairs above 10 k-ohm: NONE

Survey start time: 8:26

System checks at end of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☒ Minimum value: 0.51 Maximum value: 1.8

Pairs above 10 k-ohm: NONE

Survey end time: 8:46

Data backup:

Data backed up (check): ☐ Location:

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USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C JOHNSON, F DAY-LEWIS
Datum:
Weather conditions: Cloudy ~65°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: ~~dipdiprec~~ dipdip2drecip
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 50mV

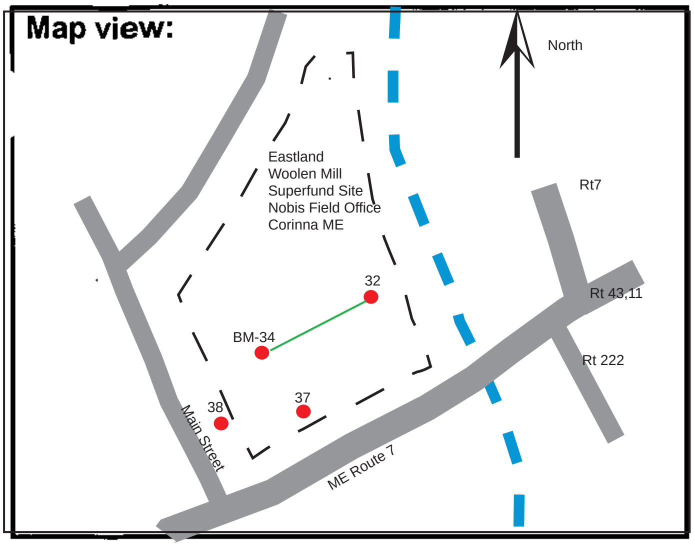
Electrode and well configuration: (note units)

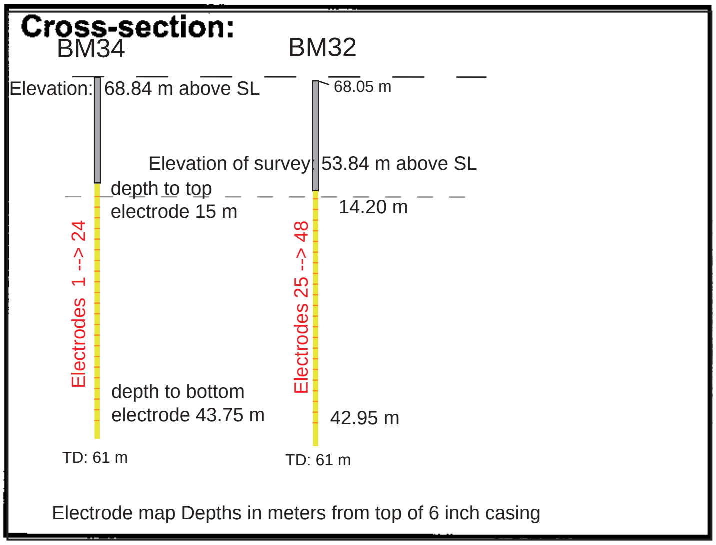
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	15m	14.2m			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	5292				

dipdip2D recip. w/ top electrode in 34 at 15m + TOC.

date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 V

Receiver battery level: 13.3V

Resistance check performed (check): ☒

Minimum value: 0.51

Maximum value: 1.8

Pairs above 10 k-ohm:

Survey start time: 8:48

System checks at end of data collection:

Transmitter battery level: 13.6 V

Receiver battery level: 13.4V

Resistance check performed (check): ☒

Minimum value: 0.46

Maximum value: 1.9

Pairs above 10 k-ohm:

Survey end time: 9:31

Data backup:

Data backed up (check): ☐

Location:

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USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy ~65°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500mS
Voltage requested: 50mV

Electrode and well configuration: (note units)

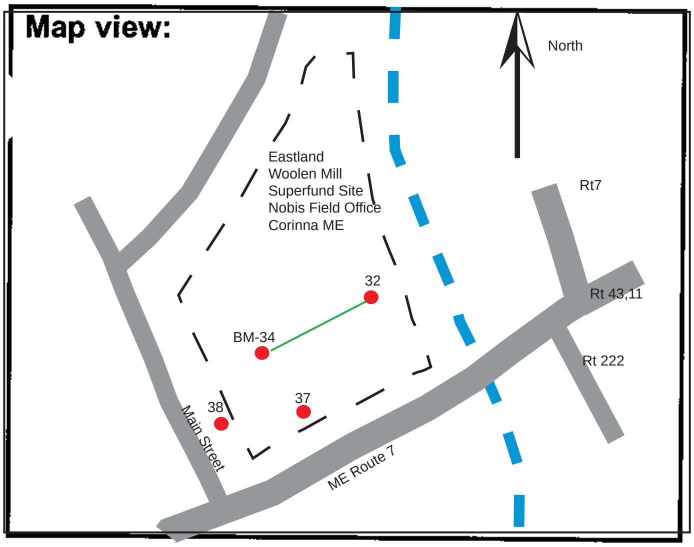
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	22.5m	21.7m			
Electrode spacing:					
Electrode type:	Steel	Steel			
Length of casing:					
Type of casing:	Steel	Steel			
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	5917				

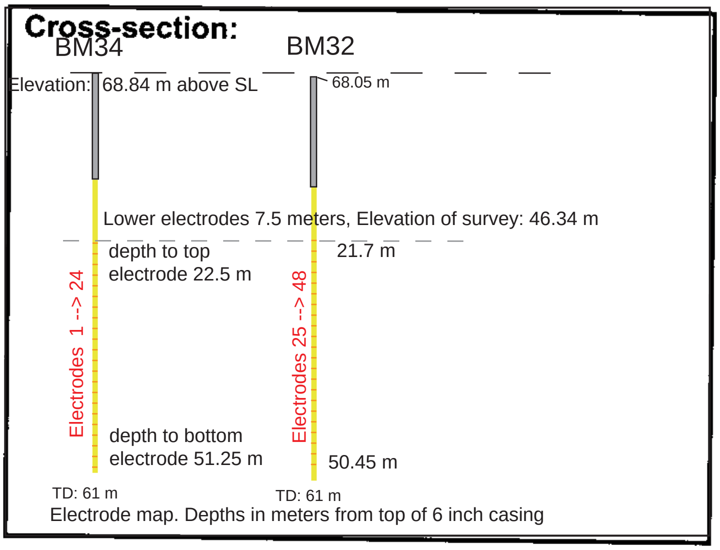
21.1

dipdip 2D @ 22.5m

date: 07/11/07

Site diagrams: (Label electrode number ranges for each well)





Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☒ Minimum value: 0.59 Maximum value: 1.96

Pairs above 10 k-ohm: NONE

Survey start time: 10:35

System checks at end of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☒ Minimum value: 0.58 Maximum value: 2.13

Pairs above 10 k-ohm: NONE

Survey end time: 10:55

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: 19T 0479434 4974227 ±8m (units) elevation 72.3m
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum: UTM WGS84
Weather conditions: Cloudy, ~65°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 50mV

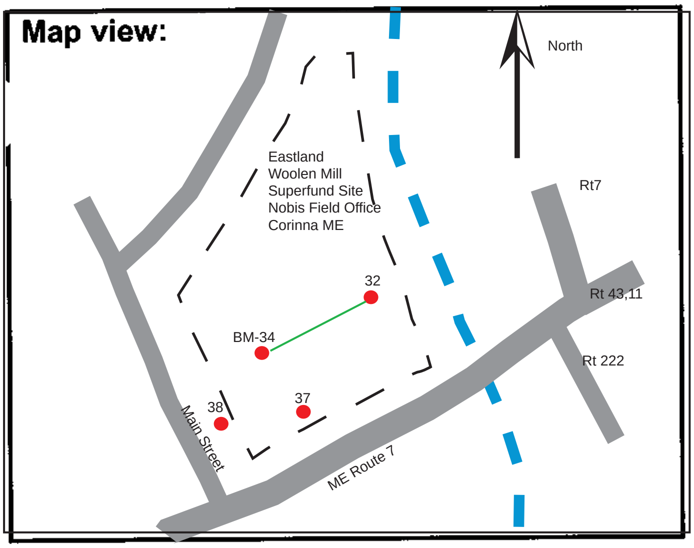
Electrode and well configuration: (note units)

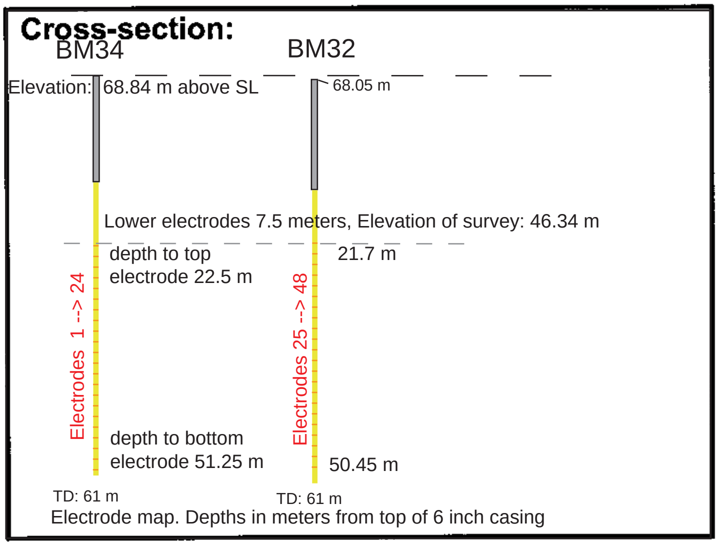
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	22.5m	21.7m			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:					
Type of casing:	Steel	Steel			
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	6542				

dipdip2drecip.txt
@ 22.5m

date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)


Map view:


Cross-section:

Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.4V

Resistance check performed (check): ☒ Minimum value: 0.58 Maximum value: 2.13

Pairs above 10 k-ohm: NONE

Survey start time:________________

System checks at end of data collection:

Transmitter battery level:________________ Receiver battery level:________________

Resistance check performed (check): ☐ Minimum value:________ Maximum value:________

Pairs above 10 k-ohm:________________

Survey end time:________________

Data backup:

Data backed up (check): ☐ Location:________________

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USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy 70°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2Drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 50 mV

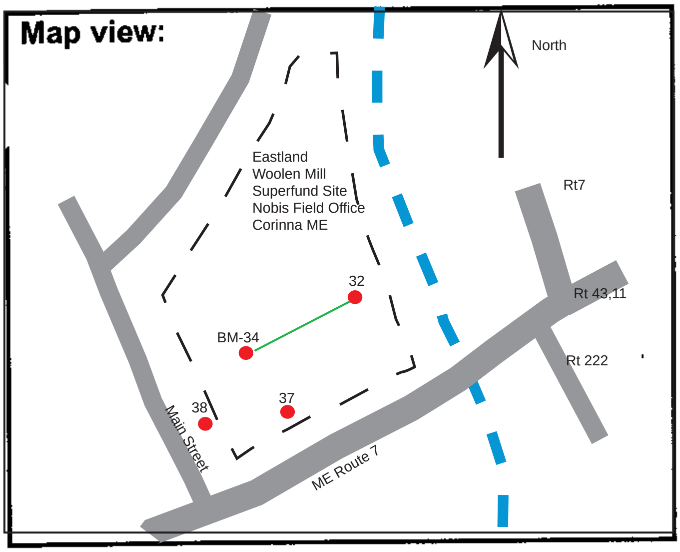
Electrode and well configuration: (note units)

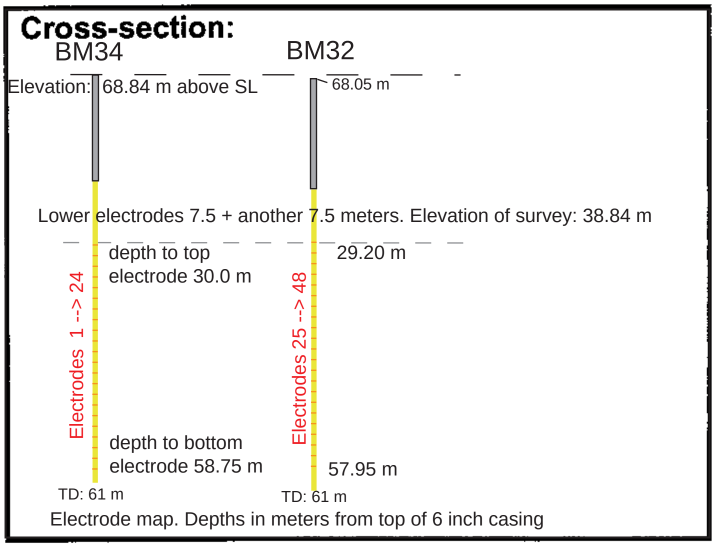
Well ID:	34	32			
Cable #:	MPT	BGAS 1			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30m	29.2m.			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:					
Type of casing:	Steel	Steel			
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	7167				

dip dip 2D recip.txt @ 30m

date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)





Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.3V

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.27

Pairs above 10 k-ohm:

Survey start time: 11:55

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.3

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.19

Pairs above 10 k-ohm:

Survey end time: ~12:45

Data backup:

Data backed up (check): ☐ Location:

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USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: ________ (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy, 70°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 50 mV

* Collected w/ only one channel

Electrode and well configuration: (note units)

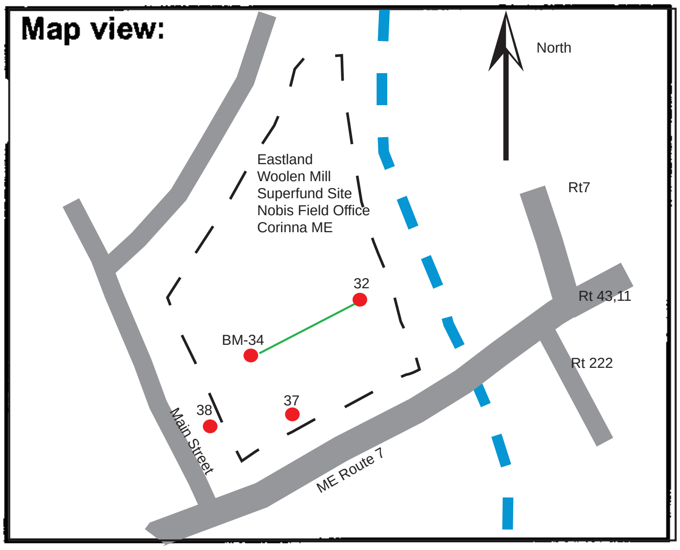
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:	-10cm.	-12.2cm			
Depth to upper electrode:	30m	29.2m			
Electrode spacing:	1.25m	1.25m			
Electrode type:	steel	Steel			
Length of casing:					
Type of casing:	Steel	Steel			
Sounded well depth:					
Screened intervals:					
Depth to water:	2.11m↓6"TOC	1.56m↓6"	TOC.		
Notes:	7792				

dipdip2d.txt
@ 30m

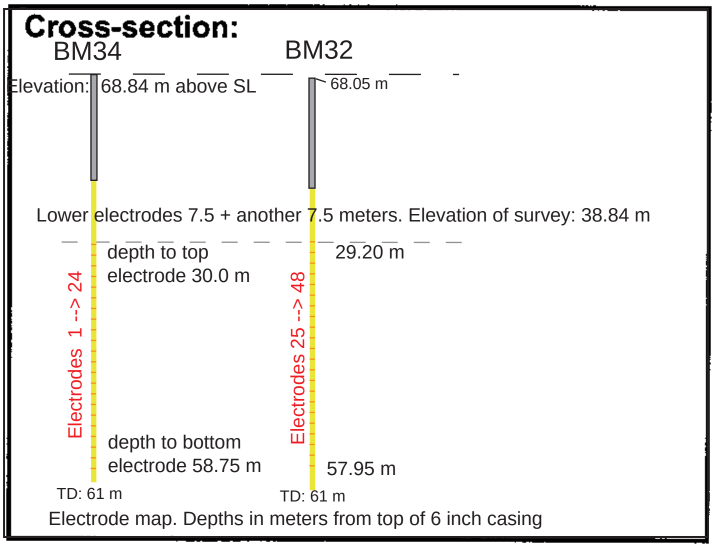
date: 07/11/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 V

Receiver battery level: 13.3V

Resistance check performed (check): ☒

Minimum value: 0.65

Maximum value: 1.18

Pairs above 10 k-ohm: NONE

Survey start time: ~ 13:00

System checks at end of data collection:

Transmitter battery level: 13.6 V

Receiver battery level: 13.4V

Resistance check performed (check): ☒

Minimum value: 0.65

Maximum value: 1.15

Pairs above 10 k-ohm:______

Survey end time: 13:45

Data backup:

Data backed up (check): ☐

Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy 70°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 1 s
Voltage requested: 50 mV

- Redoing w/ 2x the usual pulse duration.
- running w/ only 1 channel

Electrode and well configuration: (note units)

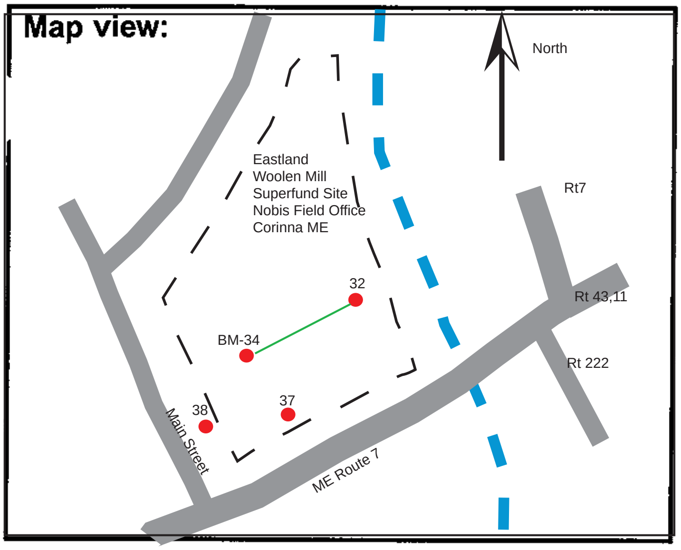
Well ID:	34	32			
Cable #:	MPT	BGAS2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30m				
Electrode spacing:	1.25m	1.25m			
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	8417				

dipdip2d.txt @ 30m
w/ pulse duration of 1 s

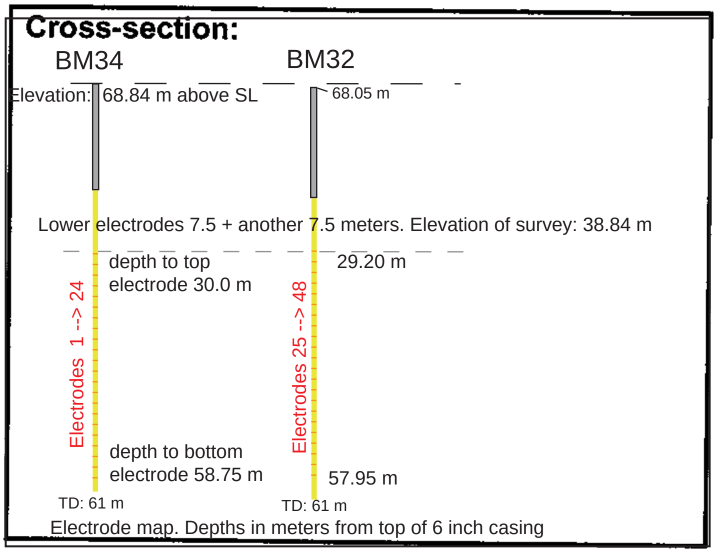
date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6V Receiver battery level: 13.3V

Resistance check performed (check): X Minimum value: 0.65 Maximum value: 1.14

Pairs above 10 k-ohm: NONE

Survey start time: ~14:00

System checks at end of data collection:

Transmitter battery level: 13.4 V Receiver battery level: 13.4V

Resistance check performed (check): X Minimum value: 0.29 Maximum value: 1.07

Pairs above 10 k-ohm: NONE

Survey end time: ~15:15

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum:
Weather conditions: Cloudy 70°F
Date: 7/11/07

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 1 s
Voltage requested: 50 mV

Redoing w/ 2x pulse duration on 1 channel.

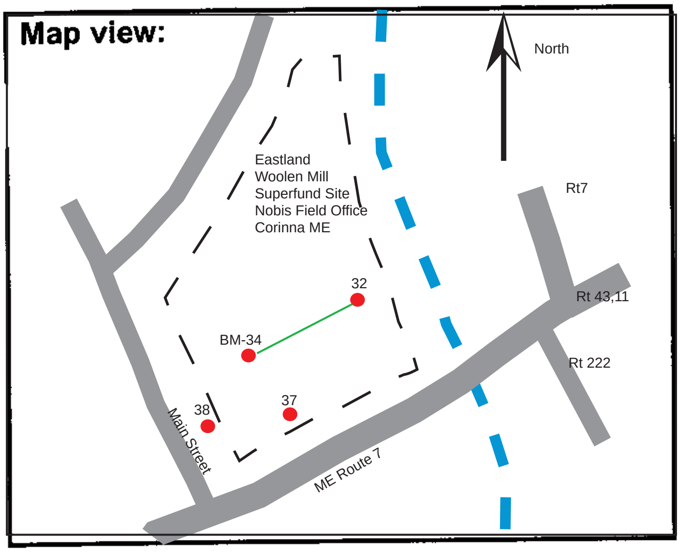
Electrode and well configuration: (note units)

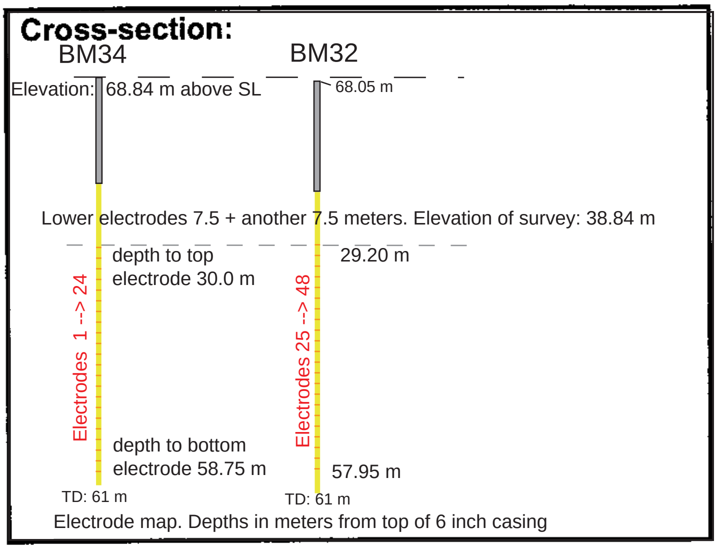
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30 m				
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	9042				

dipdip2drecip.txt w/
1s pulse duration @
30m

date: 7/11/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.4 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.32 Maximum value: 1.19

Pairs above 10 k-ohm: None

Survey start time: 15:25

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.31 Maximum value: 1.20

Pairs above 10 k-ohm: None

Survey end time: 16:35

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Cloudy, 65°F
Date: 7/12/07

Measurement and system specifications:

Geometry filename: d.pdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 250 ms
Voltage requested: 50 mV

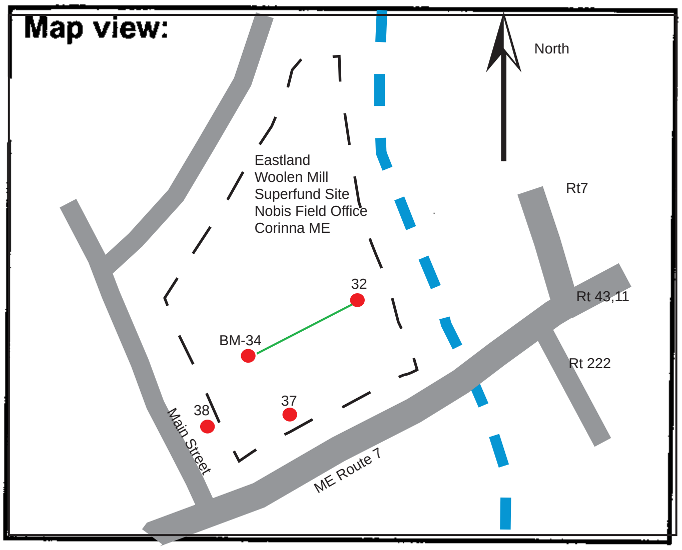
Electrode and well configuration: (note units)

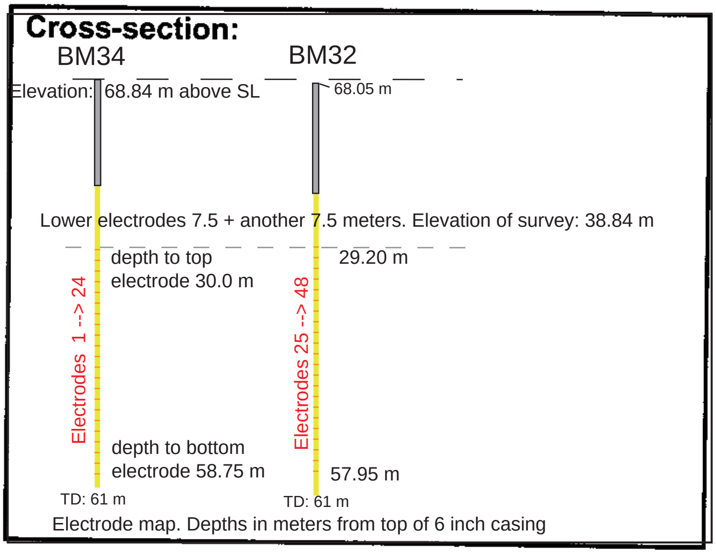
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30m				
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	9667				

dipdip 2d @ 30m
w/ 250ms pulse

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6 v Receiver battery level: 13.3v

Resistance check performed (check): ☒ Minimum value: 0.33 Maximum value: 1.19

Pairs above 10 k-ohm: NONE

Survey start time: 8:27

System checks at end of data collection:

Transmitter battery level: 13.6 Receiver battery level: 13.3

Resistance check performed (check): ☒ Minimum value: 0.31 Maximum value: 1.14

Pairs above 10 k-ohm: NONE

Survey end time: 9:03

Data backup:

Data backed up (check): ☐ Location:______

USGS Office of Ground Water Branch of Geophysics
Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Partly Sunny, 70°F
Date: 7/12/07

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 250mS
Voltage requested: 50mV

dipdip2drecip @ 30m w/ pulse of 250mS.

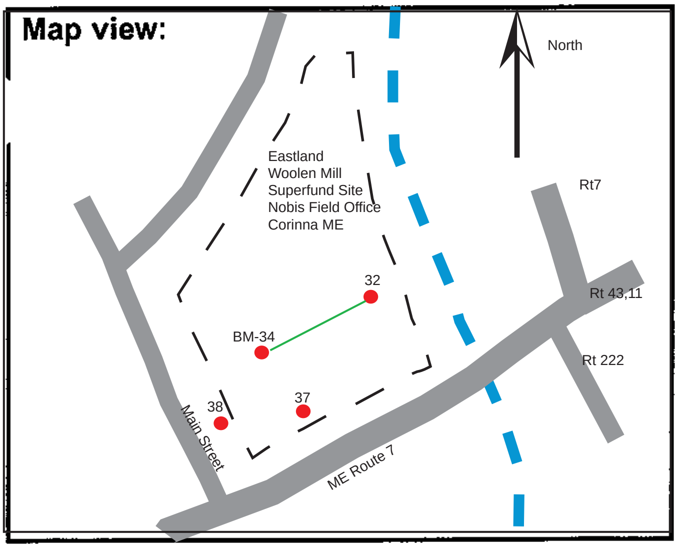
Electrode and well configuration: (note units)

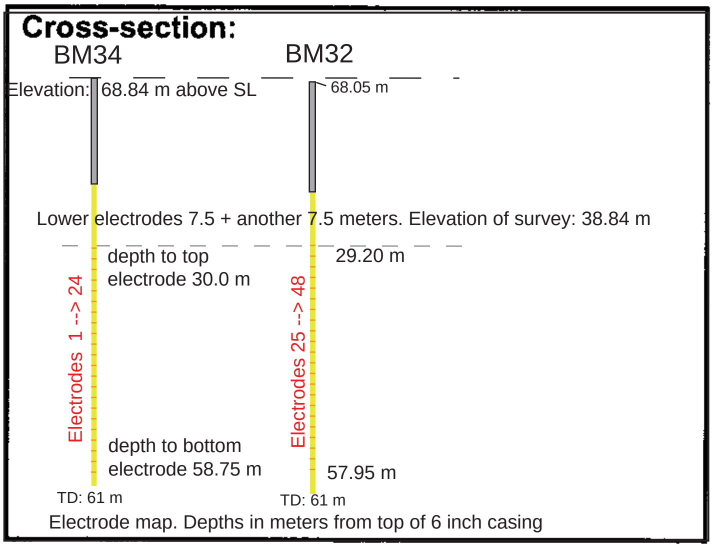
Well ID:	34	32			
Cable #:	MPT	BGAS2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30m				
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	10292				

dipdip 2d recip @ 30m
w/ 250ms pulse

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.6

Receiver battery level: 13.3

Resistance check performed (check): ☒

Minimum value: 0.31

Maximum value: 1.14

Pairs above 10 k-ohm: NONE

Survey start time: 9:05

System checks at end of data collection:

Transmitter battery level: 13.4

Receiver battery level: 13.4

Resistance check performed (check): ☒

Minimum value: 0.32

Maximum value: 1.18

Pairs above 10 k-ohm:

Survey end time: ~ 9:40

Data backup:

Data backed up (check): ☐

Location:

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Partly Sunny, 70°F
Date: 7/12/07

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24X2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ~~☒ unsigned~~
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 800mV

Electrode and well configuration: (note units)

Well ID:	34	32			
Cable #:	MPT	BGAS2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:					
Stickup:					
Depth to upper electrode:	30m				
Electrode spacing:					
Electrode type:					
Length of casing:					
Type of casing:					
Sounded well depth:					
Screened intervals:					
Depth to water:					
Notes:	10917				

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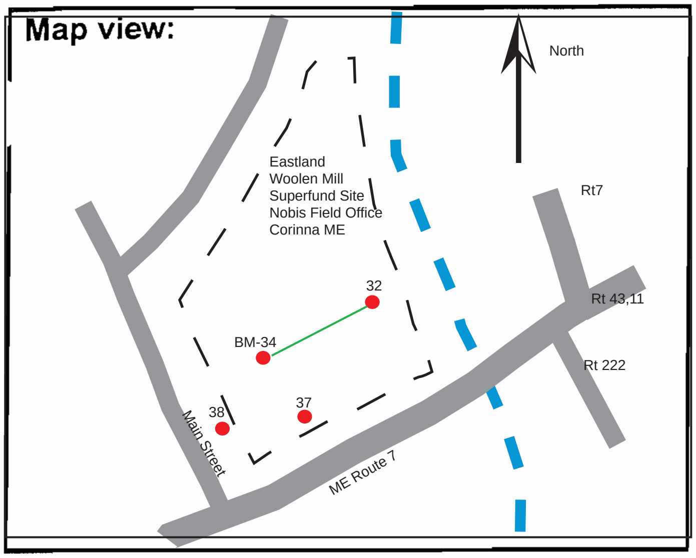
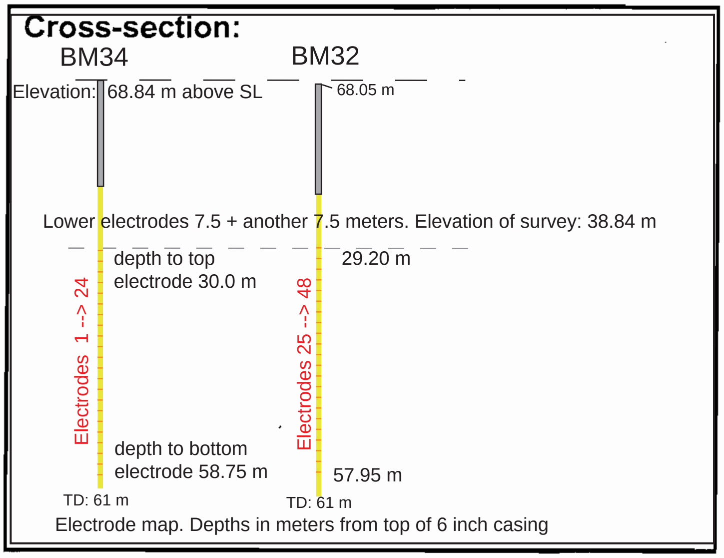
dipdip2d @ 30m
w/ 800mV and 500ms

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.4 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.32 Maximum value: 1.18

Pairs above 10 k-ohm:

Survey start time: 9:50

System checks at end of data collection:

Transmitter battery level: 12.9 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.31 Maximum value: 1.15

Pairs above 10 k-ohm: NONE

Survey end time: 10:30

Data backup:

10917

Data backed up (check): ☐ Location:

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna ME
GPS location: ____________ (units)
Operator(s): F Day Lewis / C Johnson
Datum: ____________
Weather conditions: Sunny & warm
Date: JULY 12, 2007

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename: ____________
Iris unit model/SN: ____________
Number of electrodes used: 24X2
Number of quadripoles: ____________
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☐ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☐
Injection pulse duration: 500ms
Voltage requested: 800 mV

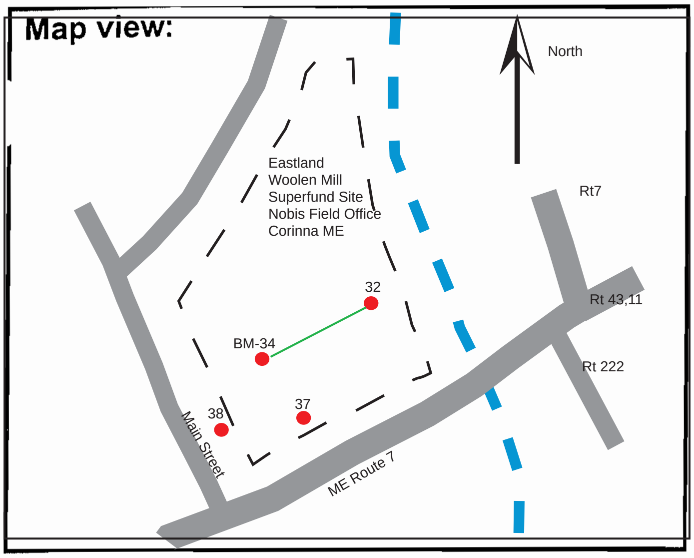
Electrode and well configuration: (note units)

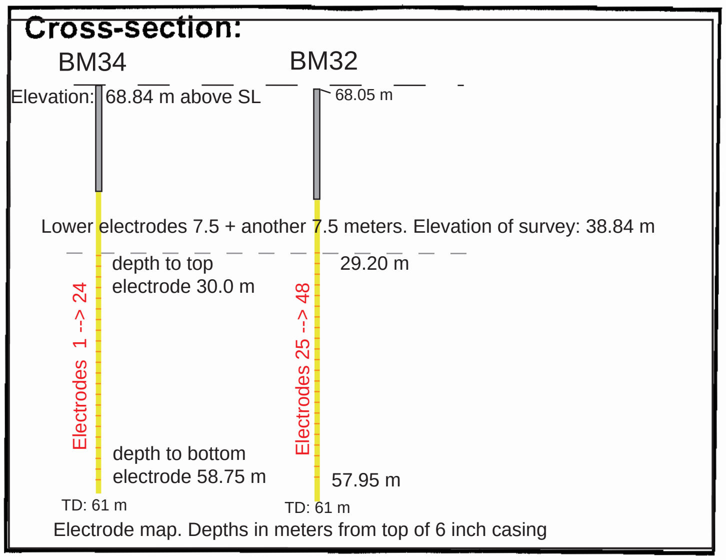
Well ID:	34	32			
Cable #:	MPT	BGA32			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84	68.05			
Stickup:	-10cm	-12cm			
Depth to upper electrode:	30m	29.2m			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:	13.7	14.6			
Type of casing:	Steel	Steel			
Sounded well depth:	61	61			
Screened intervals:					
Depth to water:					
Notes:	11542				

dipdip2drecip.txt
(@ 800mV + 500mS @ 30m

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units m

Well ID	32				
34	25.85				

System checks at start of data collection:

Transmitter battery level: 12.9 V
Receiver battery level: 13.4V
Resistance check performed (check): ☑
Minimum value: 0.31
Maximum value: 1.15
Pairs above 10 k-ohm:
Survey start time: 10:40

System checks at end of data collection:

Transmitter battery level: 12.6
Receiver battery level: 13.4
Resistance check performed (check): ☒
Minimum value: 0.31
Maximum value: 1.19
Pairs above 10 k-ohm:
Survey end time: ~11:30

Data backup:

Data backed up (check): ☐
Location:

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions:
Date: 7/12/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 800mV
w/ 10 channels

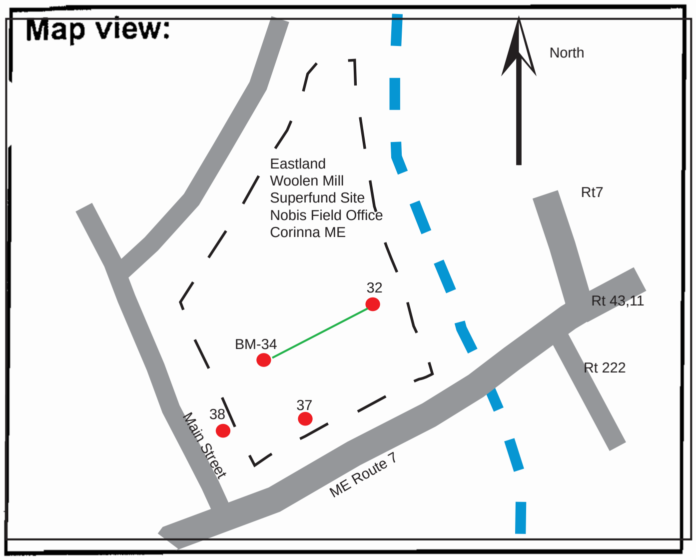
Electrode and well configuration: (note units)

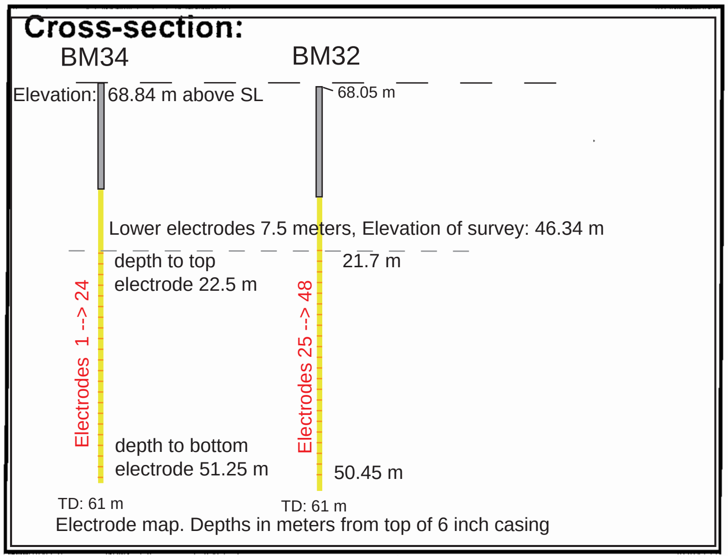
Well ID:	34	32			
Cable #:	MPT	B6AS2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84	68.05			
Stickup:	-10cm	-12cm			
Depth to upper electrode:	22.5 m	21.7 m			
Electrode spacing:	1.25 m	1.25 m			
Electrode type:	Steel	Steel			
Length of casing:	13.7 m	14.6 m			
Type of casing:	Steel	Steel			
Sounded well depth:	61 m	61 m			
Screened intervals:					
Depth to water:					
Notes:	12167				

dipdip 2d @ 22.5m
w/ 800mV +
500mS

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units_______

Well ID					

System checks at start of data collection:

Transmitter battery level: 12.4
Receiver battery level: 13.6
Resistance check performed (check): ☒
Minimum value: 0.61
Maximum value: 1.07
Pairs above 10 k-ohm: None
Survey start time: 12:34pm

System checks at end of data collection:

Transmitter battery level: 13.1
Receiver battery level: 13.4
Resistance check performed (check): ☒
Minimum value: 0.66
Maximum value: 1.92
Pairs above 10 k-ohm:
Survey end time: 12:58pm

Data backup:

Data backed up (check): ☐
Location:

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. JOHNSON, F. DAY-LEWIS
Datum:
Weather conditions: Sunny, 82°F
Date: 7/12/07

Measurement and system specifications:

Geometry filename: dipdip2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24X2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 800mV

Electrode and well configuration: (note units)

Well ID:	34	32			
Cable #:	MPT	BGA52			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84	68.05			
Stickup:	-10cm	-12cm			
Depth to upper electrode:	22.5m	21.7 m			
Electrode spacing:	1.25 m	1.25 m			
Electrode type:	Steel	Steel			
Length of casing:	13.7 m	14.6 m			
Type of casing:	Steel	Steel			
Sounded well depth:	61m	61m			
Screened intervals:	—	—			
Depth to water:					
Notes:					
	12792				

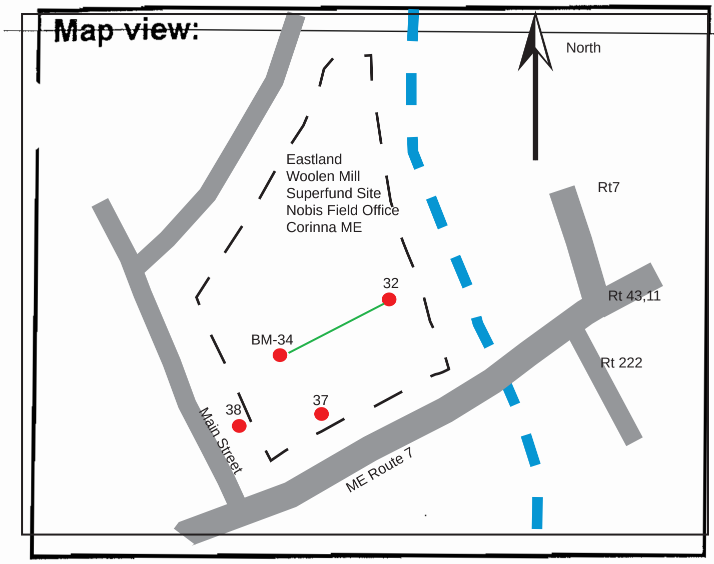
6

dipdip 2d @ 22.5m
w/ 800mV

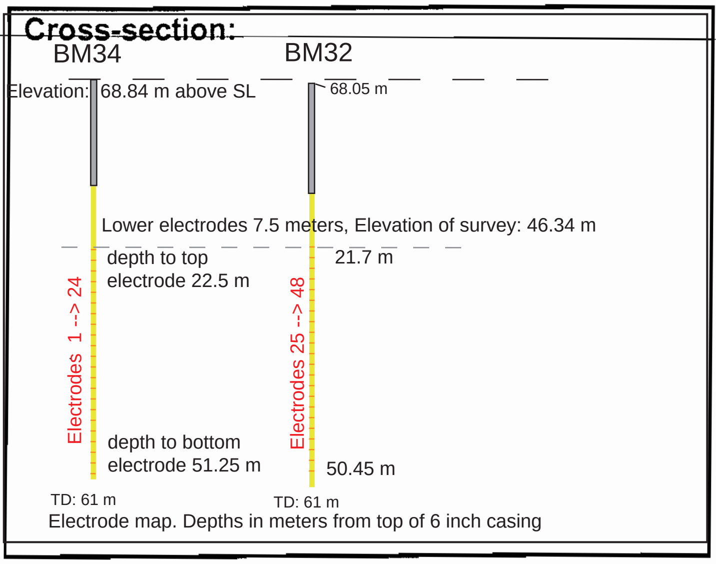
date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map. Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.1 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.92

Pairs above 10 k-ohm: NONE

Survey start time: 13:00

System checks at end of data collection:

Transmitter battery level: 12.9 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.87

Pairs above 10 k-ohm: NONE

Survey end time: 13:51

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F Day-Lewis
Datum:
Weather conditions: Sunny 85°F
Date: ~~6/~~ 7/12/07

Measurement and system specifications:

Geometry filename: d:pdp2drecip.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24x2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500 ms
Voltage requested: 800 mV

Electrode and well configuration: (note units)

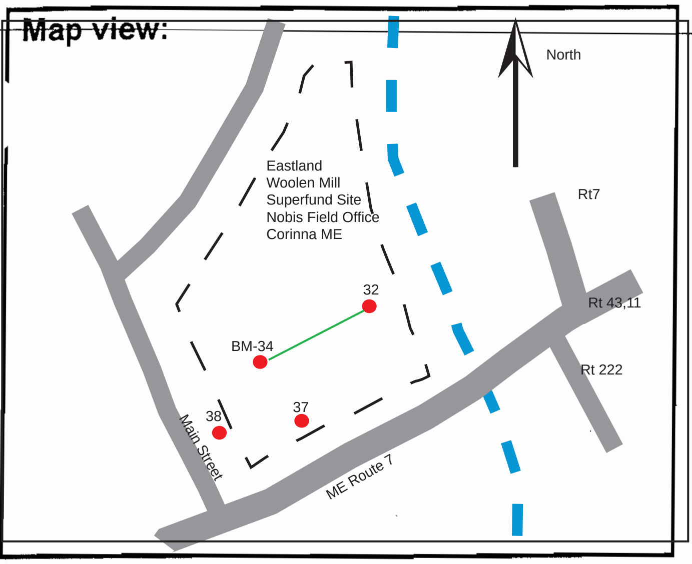
Well ID:	34	32			
Cable #:	MPT	BGAS 2			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84 m	68.05 m			
Stickup:	-10 cm	-12 cm			
Depth to upper electrode:	15 m	14.2 m			
Electrode spacing:	1.25 m	1.25 m			
Electrode type:	Steel	Steel			
Length of casing:	13.7 m	14.6 m			
Type of casing:	Steel	Steel			
Sounded well depth:	61 m	61 m			
Screened intervals:	—	—			
Depth to water:					
Notes:					
	13417				

62

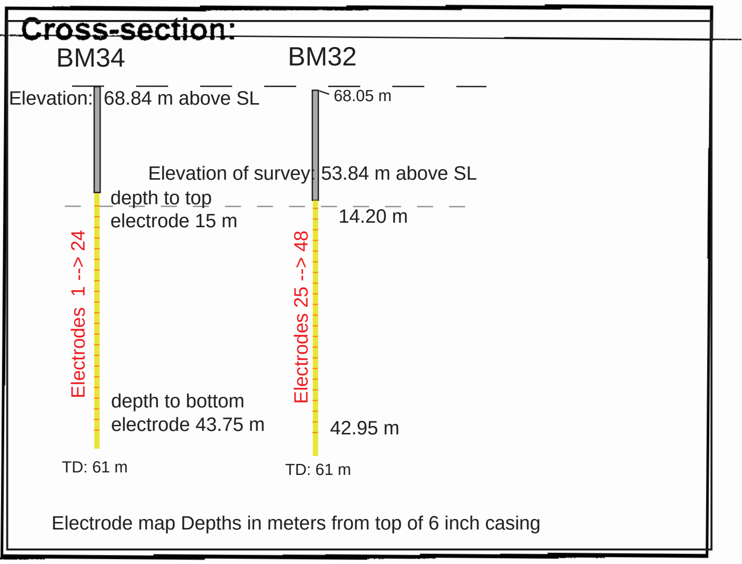
dipdip 2D recip @ 15m
w/ 800mV and 500ms) date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)

Map view:



Cross-section:



Electrode map Depths in meters from top of 6 inch casing

Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 13.1 ✓ Receiver battery level: 13.4 ✓

Resistance check performed (check): ☒ Minimum value: 0.46 Maximum value: 1.85

Pairs above 10 k-ohm:______

Survey start time:______

System checks at end of data collection:

Transmitter battery level: 12.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.84

Pairs above 10 k-ohm: None

Survey end time: 14:53

Data backup:

Data backed up (check): ☐ Location:______

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Iris Resistivity System - Borehole data collection sheet

General information:

Site location name: Corinna, ME
GPS location: (units)
Operator(s): C. Johnson, F. Day-Lewis
Datum:
Weather conditions: Sunny ~85°F
Date: 7/12/07

Measurement and system specifications:

Geometry filename: dipdip2d.txt
Units (check one): ☒ meters ☐ feet
Data filename:
Iris unit model/SN:
Number of electrodes used: 24 x 2
Number of quadripoles: 625
Number of stacks minimum/maximum: 2 / 3
Voltage (check one): ☒ signed ☐ unsigned
Requested standard deviation: 2%
Reciprocal data?: ☒
Injection pulse duration: 500ms
Voltage requested: 800mV

Electrode and well configuration: (note units)

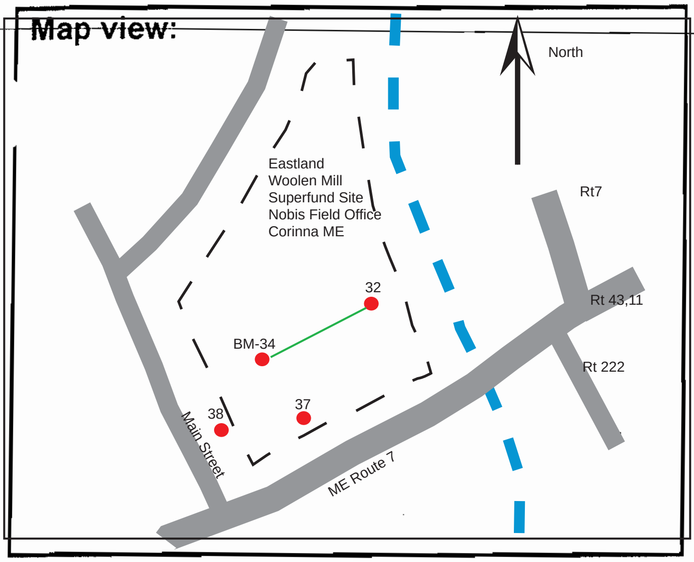
Well ID:	34	32			
Cable #:	MPT	BGts			
Electrodes (# – #):	1-24	25-48			
Elevation at TOC:	68.84m	68.05m			
Stickup:	−10 cm	−12 cm			
Depth to upper electrode:	15m	14.2m			
Electrode spacing:	1.25m	1.25m			
Electrode type:	Steel	Steel			
Length of casing:	13.7m	14.6m			
Type of casing:	Steel	Steel			
Sounded well depth:	61m	61m			
Screened intervals:	—	—			
Depth to water:					
Notes:	14042				

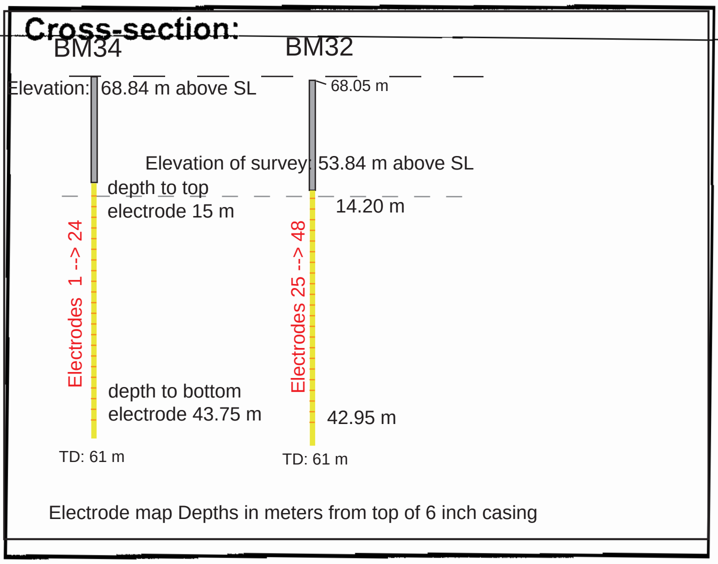
6

dip dip 2d w/
800 mV @ 15m

date: 7/12/07

Site diagrams: (Label electrode number ranges for each well)





Well offsets: units______

Well ID					

System checks at start of data collection:

Transmitter battery level: 12.6 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.66 Maximum value: 1.84

Pairs above 10 k-ohm: None

Survey start time: 14:55

System checks at end of data collection:

Transmitter battery level: 12.5 Receiver battery level: 13.4

Resistance check performed (check): ☒ Minimum value: 0.61 Maximum value: 1.98

Pairs above 10 k-ohm: NONE

Survey end time: 15:09

Data backup:

Data backed up (check): ☐ Location:______

Appendix 3. Inversion parameter files for Res2DInv

File epa.ivp for inversions of BM-34/BM-38, BM-34/BM-37, BM-37/BM-38

```
Inversion settings
Initial damping factor
0.1600
Minimum damping factor
0.0100
Line search option
2
Convergence limit
5.0000
Minimum change in RMS error
0.4000
Number of iterations
5
Vertical to horizontal flatness filter ratio
0.5000
Model for increase in thickness of layers(0=default 10, 1=default 25,
2=user defined)
2
Number of nodes between adjacent electrodes
4
Flatness filter type, Include smoothing of model resistivity
1
Reduce number of topographical datum points?
0
Carry out topography modeling?
1
Type of topography trend removal
0
Type of Jacobian matrix calculation
1
Increase of damping factor with depth
1.0500
Type of topographical modeling
0
Robust data constrain?
1
Cutoff factor for data constrain
0.0500
Robust model constrain?
0
Cutoff factor for model constrain
0.0050
Allow number of model parameters to exceed datum points?
1
Use extended model?
0
Reduce effect of side blocks?
2
Type of mesh
0
Optimise damping factor?
1
```

```
Time-lapse inversion constrain
0
Type of time-lapse inversion method
0
Thickness of first layer
0.5000
Factor to increase thickness layer with depth
1.1000
USE FINITE ELEMENT METHOD (YES=1,NO=0)
1
WIDTH OF BLOCKS (1=NORMAL WIDTH, 2=DOUBLE, 3=TRIPLE, 4=QUADRAPLE,
5=QUINTIPLE)
1
MAKE SURE BLOCKS HAVE THE SAME WIDTH (YES=1,NO=0)
1
RMS CONVERGENCE LIMIT (IN PERCENT)
1.000
USE LOGARITHM OF APPARENT RESISTIVITY (0=USE LOG OF APPARENT
RESISTIVITY, 1=USE RESISTANCE VALUES, 2=USE APPARENT RESISTIVITY)
1
TYPE OF IP INVERSION METHOD (0=CONCURRENT,1=SEQUENTIAL)
0
PROCEED AUTOMATICALLY FOR SEQUENTIAL METHOD (1=YES,0=NO)
0
IP DAMPING FACTOR
0.100
USE AUTOMATIC IP DAMPING FACTOR (YES=1,NO=0)
0
CUTOFF FACTOR FOR BOREHOLE DATA (0.0005 to 0.02)
0.00300
TYPE OF CROSS-BOREHOLE MODEL (0=normal,1=halfsize)
1
LIMIT RESISTIVITY VALUES(0=No,1=Yes)
0
Upper limit factor (10-50)
50.000
Lower limit factor (0.02 to 0.1)
0.020
Type of reference resistivity (0=average,1=first iteration)
0
Model refinement (1.0=Normal,0.5=Half-width cells)
0.50
Combined Combined Marquardt and Occam inversion (0=Not used,1=used)
0
Type of optimisation method (0=Gauss-Newton,2=Incomplete GN)
2
Convergence limit for Incomplete Gauss-Newton method
0.005
Use data compression with Incomplete Gauss-Newton (0=No,1=Yes)
0
Use reference model in inversion (0=No,1=Yes)
0
Damping factor for reference model
0.00500
Use fast method to calculate Jacobian matrix. (0=No,1=Yes)
1
Use higher damping for first layer? (0=No,1=Yes)
```

```
0
Extra damping factor for first layer
1.50000
Type of finite-element method (0=Triangular,1=Trapezoidal elements)
0
```

File epa34_32.ivp for inversions of BM-34/BM-38, BM-34/BM-37, BM-37/BM-38

```

Inversion settings
Initial damping factor
0.2500
Minimum damping factor
0.1000
Line search option
2
Convergence limit
5.0000
Minimum change in RMS error
0.4000
Number of iterations
5
Vertical to horizontal flatness filter ratio
0.5000
Model for increase in thickness of layers(0=default 10, 1=default 25,
2=user defined)
2
Number of nodes between adjacent electrodes
4
Flatness filter type, Include smoothing of model resistivity
1
Reduce number of topographical datum points?
0
Carry out topography modeling?
1
Type of topography trend removal
0
Type of Jacobian matrix calculation
1
Increase of damping factor with depth
1.0500
Type of topographical modeling
0
Robust data constrain?
1
Cutoff factor for data constrain
0.0500
Robust model constrain?
0
Cutoff factor for model constrain
0.0050
Allow number of model parameters to exceed datum points?
```

```
1
Use extended model?
0
Reduce effect of side blocks?
2
Type of mesh
0
Optimise damping factor?
1
Time-lapse inversion constrain
0
Type of time-lapse inversion method
0
Thickness of first layer
0.5000
Factor to increase thickness layer with depth
1.1000
USE FINITE ELEMENT METHOD (YES=1,NO=0)
1
WIDTH OF BLOCKS (1=NORMAL WIDTH, 2=DOUBLE, 3=TRIPLE, 4=QUADRAPLE,
5=QUINTIPLE)
1
MAKE SURE BLOCKS HAVE THE SAME WIDTH (YES=1,NO=0)
1
RMS CONVERGENCE LIMIT (IN PERCENT)
1.000
USE LOGARITHM OF APPARENT RESISTIVITY (0=USE LOG OF APPARENT
RESISTIVITY, 1=USE RESISTANCE VALUES, 2=USE APPARENT RESISTIVITY)
1
TYPE OF IP INVERSION METHOD (0=CONCURRENT,1=SEQUENTIAL)
0
PROCEED AUTOMATICALLY FOR SEQUENTIAL METHOD (1=YES,0=NO)
0
IP DAMPING FACTOR
0.100
USE AUTOMATIC IP DAMPING FACTOR (YES=1,NO=0)
0
CUTOFF FACTOR FOR BOREHOLE DATA (0.0005 to 0.02)
0.00300
TYPE OF CROSS-BOREHOLE MODEL (0=normal,1=halfsize)
1
LIMIT RESISTIVITY VALUES(0=No,1=Yes)
0
Upper limit factor (10-50)
50.000
Lower limit factor (0.02 to 0.1)
0.020
Type of reference resistivity (0=average,1=first iteration)
0
Model refinement (1.0=Normal,0.5=Half-width cells)
0.50
Combined Combined Marquardt and Occam inversion (0=Not used,1=used)
0
Type of optimisation method (0=Gauss-Newton,2=Incomplete GN)
2
Convergence limit for Incomplete Gauss-Newton method
0.005
```

```
Use data compression with Incomplete Gauss-Newton (0=No,1=Yes)
0
Use reference model in inversion (0=No,1=Yes)
0
Damping factor for reference model
0.00500
Use fast method to calculate Jacobian matrix. (0=No,1=Yes)
1
Use higher damping for first layer? (0=No,1=Yes)
0
Extra damping factor for first layer
1.50000
Type of finite-element method (0=Triangular,1=Trapezoidal elements)
0
```