Geometrical Well Spacing in Kingdom

IHS Markit is committed to providing impactful, accurate computations to our clients. In furtherance of this objective, we have recently incorporated strong geometrical computations into Kingdom to calculate well spacing in two dimensions if the interest is the same reservoir level, and three dimensions when the interest is analyzing the drainage impact in stacked reservoirs. Accurate well spacing computations are critical to better assess the impact on production performance. Kingdom also provides a production performance prediction workflow which integrates geological, geophysical, and engineering data as well as wellbore geometry and spacing variables to create sweet spot maps, to analyze the impact of every variable on production, and to estimate reserves.

Following are detailed discussions of the multiple scenarios that Kingdom can handle when dealing with well spacing computation:

- Compute the horizontal section of every well
- Create a distance log per well in 2D or 3D
- Compute the two nearest wells at every deviation survey point in 2D or 3D
- Create a distance grid

It is important to mention that in every computation, it is necessary to select the wells on which the computations are to be made. Kingdom provides the flexibility to create well subsets according to the relevant criteria of interest. Sample subset criteria might be as follows: 1) Horizontal wells producing from a specific formation, 2) All the wells from a specific pad,3) Horizontal wells from a specific formation drilled before any given date. Kingdom's well query tool provides a wide range of criteria to group wells.

Compute Horizontal Section

Finding the horizontal section of every well is the first critical step in well spacing. Kingdom's Well Explorer provides a computation tool that extracts the first and last stage perforation depths, which would ideally provide the stimulated lateral length. Additionally, if the stage data is not fully available for the user, Kingdom provides other options on what depth to start the computations, like formation tops, user specified inclination angle, or at the intersection with the wells with a structural grid. Once the starting point has been defined, all subsequent measurements on all wells will start at the defined point. Segments above the starting point won't be included in the computations.

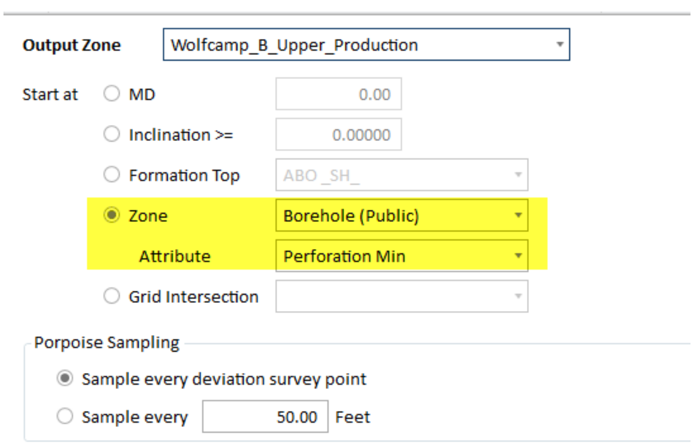

Figure 1. Select the starting point for every well geometry or well spacing computation. In this example, the first perforation depth for every horizontal well was previously extracted in Well Explorer.

Distance Log

This Distance Log Computation generates a digital curve of the measured depth of the borehole, and the distance to the nearest borehole or to a selected borehole. The depth values are based on the deviation survey points, or a specified sample rate along the wellbore. The specified sample rate option allows the user to set the rate to match the sample rate of the other digital curves.

When computing a single distance log track to the nearest borehole, the nearest borehole may change from point to point depending on the orientation of the nearby wells. The value at each point in the computed log is the value to the nearest borehole. The user can also compute a distance log to a specified borehole. In this case, multiple logs can be generated for a single borehole tracking the distance to other selected wells.

To further refine the distance log, the user can specify the starting point of the distance log computation. For example, in the figure below, the distance log is computed from the perforation minimum depth to the perforation maximum depth.

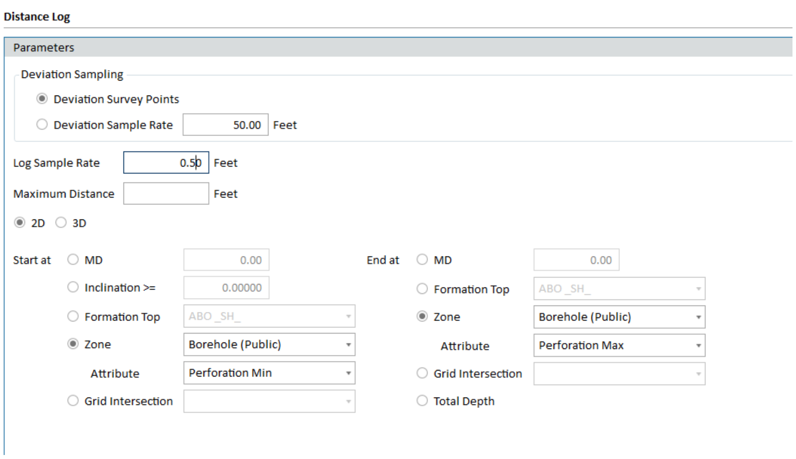

Figure 2. Distance log parameters. Computations can be done at every deviation survey point along the selected section, or it can be even more detailed by using a specified sample rate. In this example the distance log for all the wells will be computed only in the depth range of the perforated stages.

This computation is useful in cases where the user wants to extract multiple statistics from the distance log (i.e. minimum, maximum, average, modes, etc.), over the entire length of the horizontal section, or if the user wants to restrict the computations to zones (i.e. formations) or even per interval (i.e. stage level).

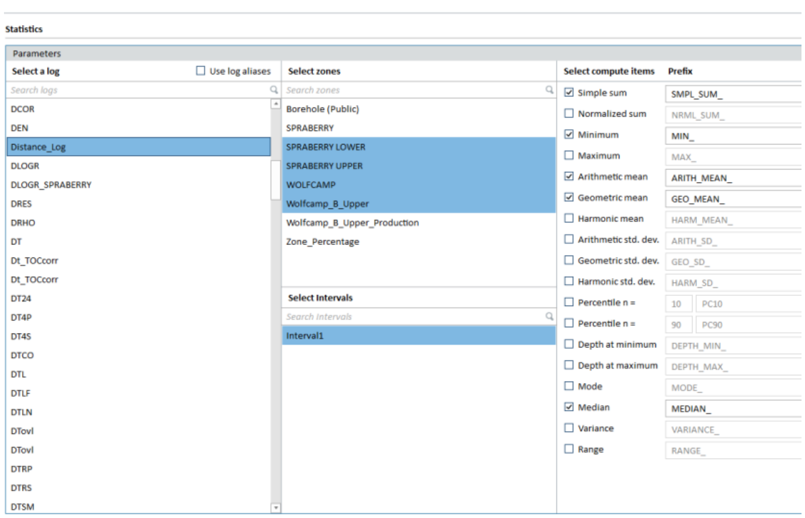

Figure 3. The computed distance log can be used to more accurately extract distance statistics over a zone or even intervals.

To assign the distance value at every deviation survey point or at every regular sample point along the wellbore, the algorithm computes a radial distance until it reaches the nearest well in any direction.

The algorithm also allows the user to specify a maximum distance cutoff value. If the radial distance grows to the specified maximum distance cutoff and no neighbor wellbore is found, then the value assigned to that point will be the maximum distance cutoff.

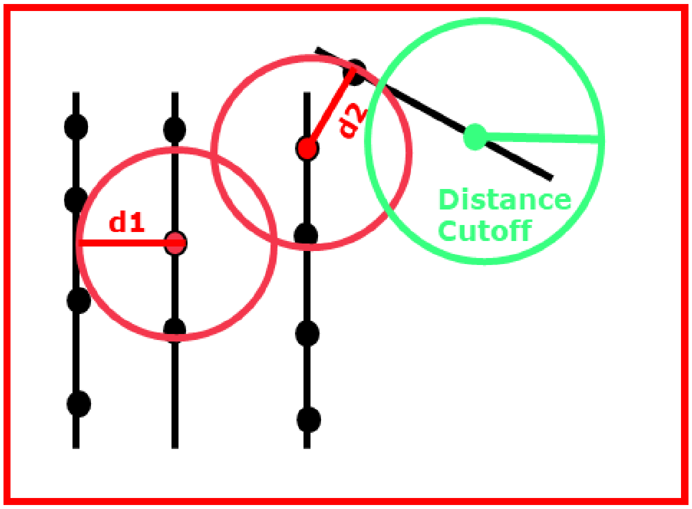

Figure 4. At every deviation survey point or selected point from sample rate, Kingdom computes the nearest distance in 2D or 3D. Three examples are provided in the picture above. Notice that the green circle corresponds to the distance cutoff; if no wellbore is reached, the recorded distance for that point is the user-defined distance cutoff.

When targeting stack formations, this computation can also be done in 3D. Here, a sphere is generated in all directions to find the nearest well.

Computing two nearest wellbores in 2D and 3D

There is another option for well spacing computation in Kingdom available within Kingdom Analytics Explorer for Spotfire. This methodology is restricted to calculations along the deviation survey points only, and rather than a log, it creates additional columns in the deviation survey table. Using the same radial search methodology explained above, the algorithm looks for the two nearest wells and generates the following four columns:

- The distance to the nearest wellbore
- The nearest wellbore UWI
- The distance to the second nearest wellbore
- The UWI of the second nearest wellbore.

The computations are dynamic, meaning that the user can modify the first computation point on the fly and immediately see the resulting changes in the summary tables.

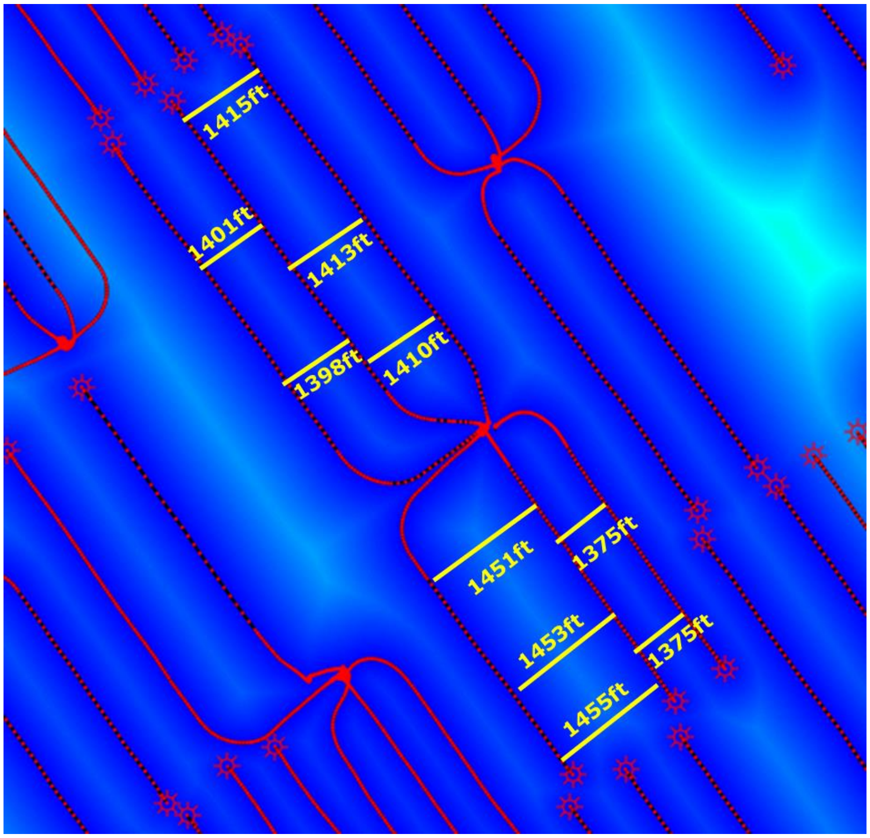

Figure 5. Spatial Explorer display of horizontal wells. Kingdom Well Spacing computes distances from every deviation survey point to the two nearest wells. Notice how the distances along the wellbores change. This allows for more accurate assessments of well spacing at every point, not just the restricted heel, toe or midpoint values.

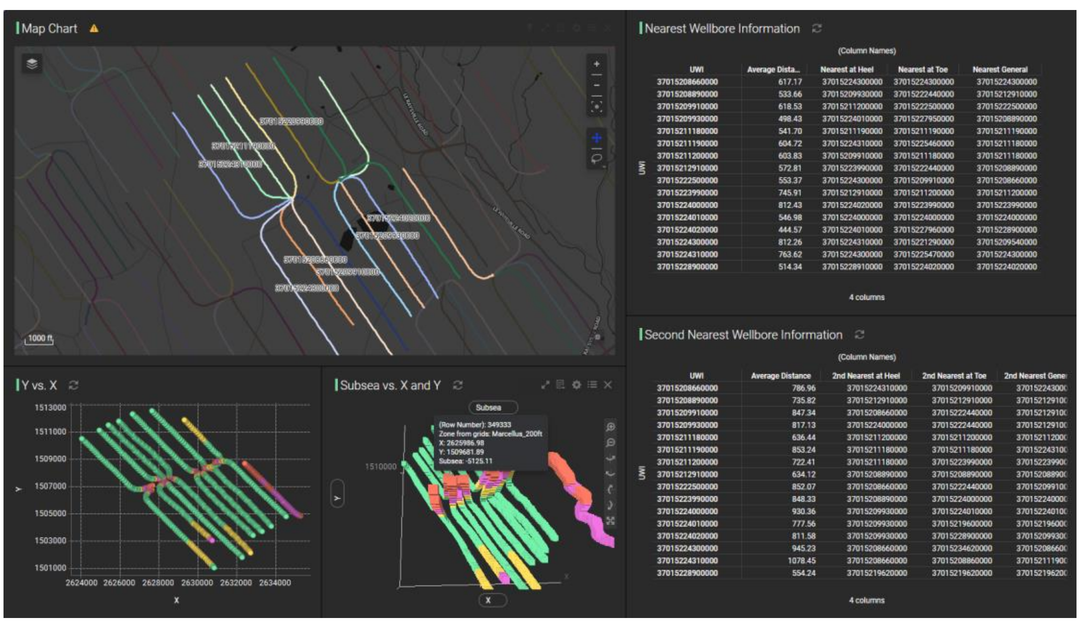

Figure 6. Kingdom Analytics Explorer for Spotfire. Well Spacing for the highlighted wells has been computed, Kingdom knows the distances at every deviation survey point to the two nearest wellbores. This image presents a summary table identifying the two nearest wells, distance at heel and toe, and average distance along the lateral.

Distance Grid

Another computation regarding inter-well spacing is the distance grid. This methodology takes all the active survey points from all input wells and generates a grid using the nearest neighbor algorithm. This computation is useful when the users are interpreting sweet spot mappings based on a set of properties. When the sweet spot areas are identified, it is necessary to account for the areas that have already been drained. This distance map can be used to intersect the sweet spot map, overlaying the two grids to identify the true remaining potential areas.

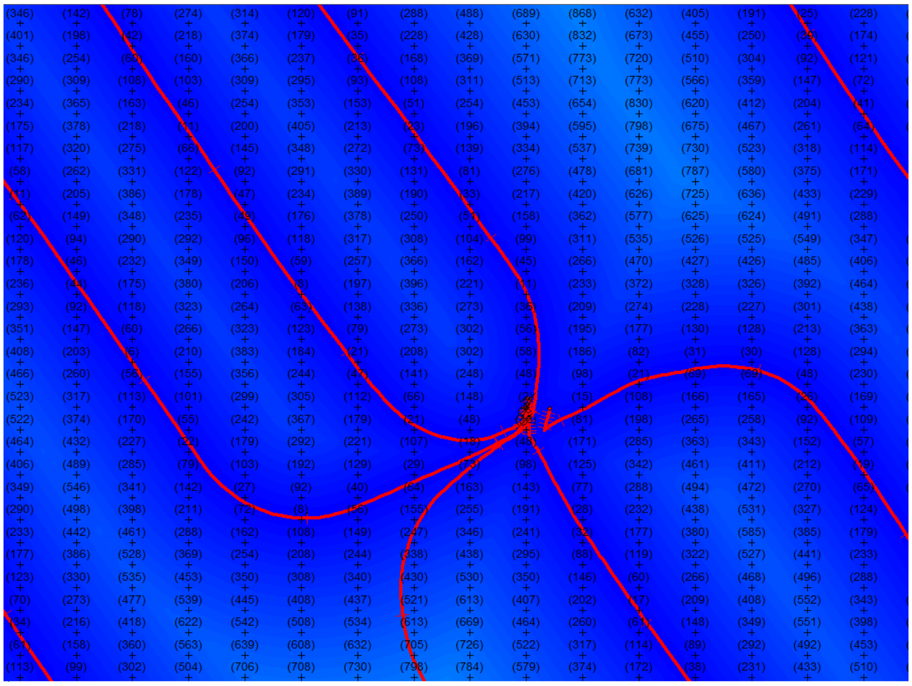

Figure 7. Picture showing distance grid values using nearest neighborhood algorithm. The grid resolution is controlled by the user.

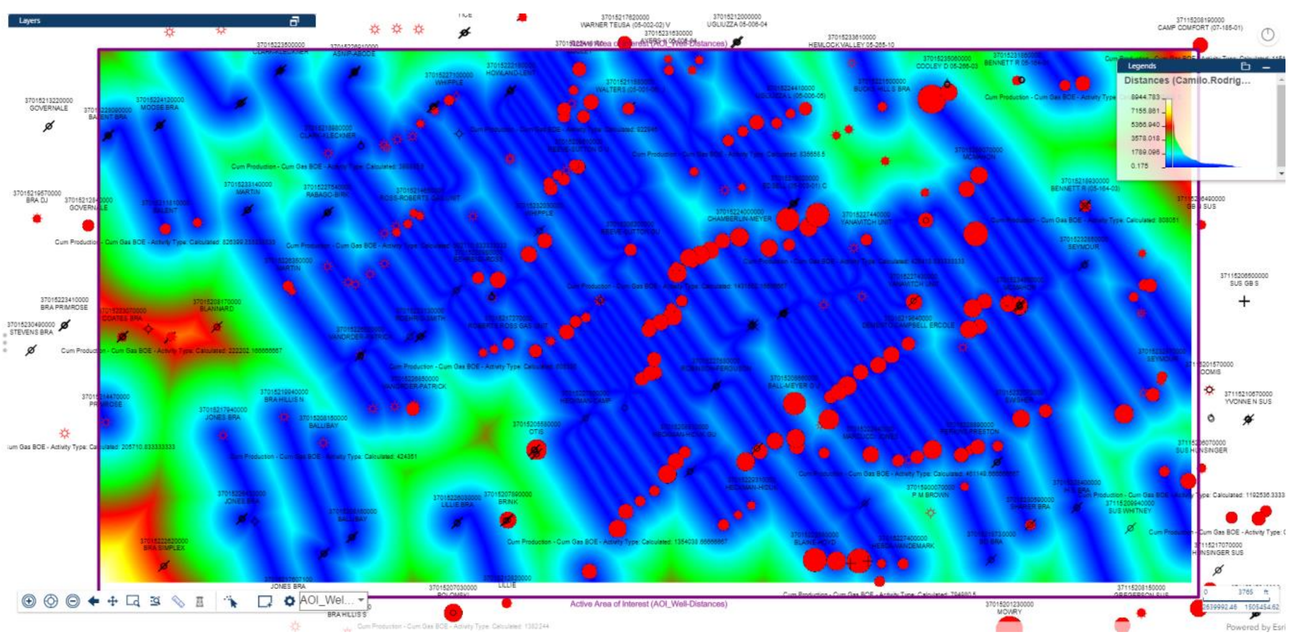

Figure 8. Example of distance grid map. Dark blue corresponds to about 1000ft buffer around the laterals.

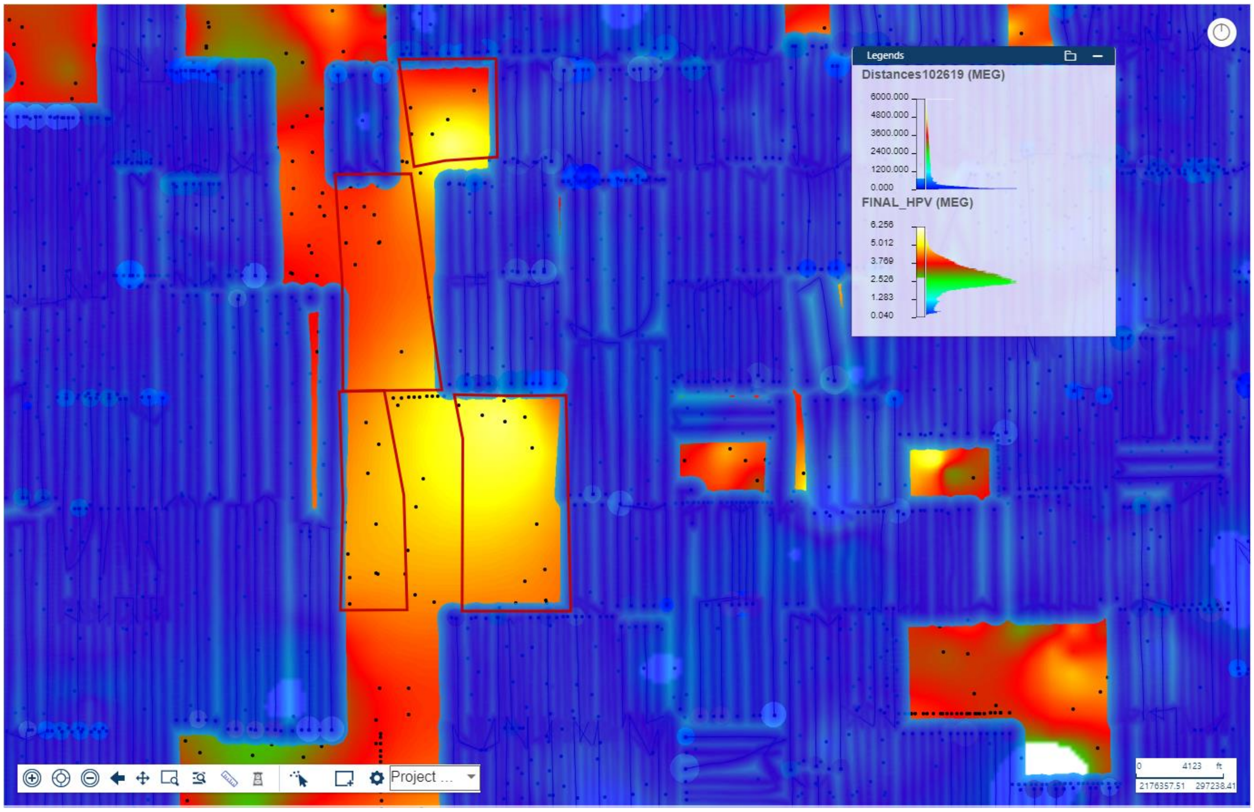

Figure 9. Map showing two grids. Hydrocarbon pore volume grid (red and yellow colors correspond to high HPV areas) and distances grid (blue color represents less than 1000 ft separation between wells. Notice that distances greater that 1000 ft are transparent in the map). By overlaying both grids we can see the remaining high HPV areas; the other areas are already covered by wells.