Question 1: Use GIS to calculate the spatial coordinates of the centre point of the cholera outbreak. Explain your methodology using the appropriate technical vocabulary (Max. 150 words).

After adding a base map and georeferencing John Snow's Cholera map as a feature, I was able to use to create my own layer data for the spatial coordinates of cases of cholera based on the featured map. To do this I created a point vector layer and in reference to John Snow's map, I plotted the geographic location of each cholera case. In addition to adding a point coordinate for each location of cholera case, I also attributed a size value to each point as to convert the value of each bar in the John Snow map to point data. To find the central point of my data layer, I had to find the location that minimises the total straight-line distance between all the points in my layer. QGIS can analyse vector data to determine the central point of a data with a tool called 'Mean Coordinate(s)', this allowed me to determine that the spatial coordinates for the centre point of the cholera outbreak were (51.513, -0.136).

Question 2: Use GIS to calculate the distance of each well pump from the centre of the cholera outbreak. Tabulate your answers in order of distance. Which well pump is closest to the centre of the outbreak, and which is second closest? Explain your methodology using the appropriate technical vocabulary (Max. 150 words).

The closest well pump to the centre of the cholera outbreak (51.513, -0.136) was the Broad Street pump, which was 27.3 metres away, and the second closest was the Bridle Street pump which was 204.3 metres away. To analyse the spatial relationship between the Soho well pumps and the centre of the cholera outbreak, I created a point vector layer, plotting the spatial coordinates of each well pump. I was then able to use the 'Distance Matrix' tool within QGIS, allowing me to create connections between a destination hubs layer (centre of the outbreak) and a source points layer (location of well pumps). QGIS calculates distance using the Euclidean distance formula, applying Pythagoras' theorem to the difference in north-south distance and the east-west distance between points. The tool created an output point layer with all the point coordinates of the well pumps, with new attributes for their distance from the centre of the cholera outbreak (figure 1).

Figure 1: A table to show the distance of each well pump in John Snow's 1854 cholera map from the centre of the cholera outbreak in metres.

Water Pump	Distance from Centre of Outbreak (metres)
Broad Street	27.3
Bridle Street	204.3
Upper Rupert Street	228.8
Carnaby Street	237.3
Warwick Street	266
Marlborough Mews	294.6
Berners Street	309.6
Dean Street	338.3
Newman Street	346.6
Castle Street East	385.7
Tichborne Street	395.1
Oxford Market	412.9
Vico Street	422.8

Question 3: Find the area closer to the contaminated broad street pump than to any other pump? Express your answer in square meters. Explain your methodology using the appropriate technical vocabulary (Max. 150 words).

The area closest to the contaminated broad street pump than any other consists of 55,141 square metres (figure 2). To be able to find a representation of the area of a geographical feature in QGIS, I created a polygon vector layer. As I was previously working only with point vector layers, I needed to divide the geospatial data into regions to represent the area of influence around each well pump point. To do this I created a polygon vector layer by using the ‘voronoi polygons’ tool within QGIS that shows the distribution of points through creating shapes. For each point the tool creates a corresponding region that consists of the region closer to that point than any other. After this I was able to calculate the area of the geometry feature using the field calculator within QGIS.

Figure 2: A Voronoi polygon vector layer showing the area closest to the contaminated Broad Street pump than to any other pump, consisting of an area of 55.141 m^2**.**

Question 4: Use GIS to count the number of cholera cases closer to the contaminated broad street pump than to any other pump. Repeat this for all the other pumps in the study area, and tabulate your conclusions. Explain your methodology using the appropriate technical vocabulary (Max. 200 words).

Within the region closest to the contaminated broad street pump than to any other pump, there were 309 cases of cholera. By creating a Voronoi polygon vector layer, for each pump I had a polygon shape for the region closest to that pump than any other. I had also previously plotted a point vector layer for the spatial location of each cholera case and correspondently attributed a size value to each point in reference to John Snow’s black bars. I could then calculate the number of cholera cases in each region closest to a specific pump than to any others. Therefore, I had multiple layers that I needed to combine to synthesize complex information about the geographic features. To do this I analyse my point and polygon layers together to extract information about how many cases fall within the bounds of each polygon. I use the 'count points-in-polygon' vector analysis tool to do so. As I had attributed a weight value to each point (number of cases per point), I calculate the sum of the weight field for each point contained by each polygon (figure 3).

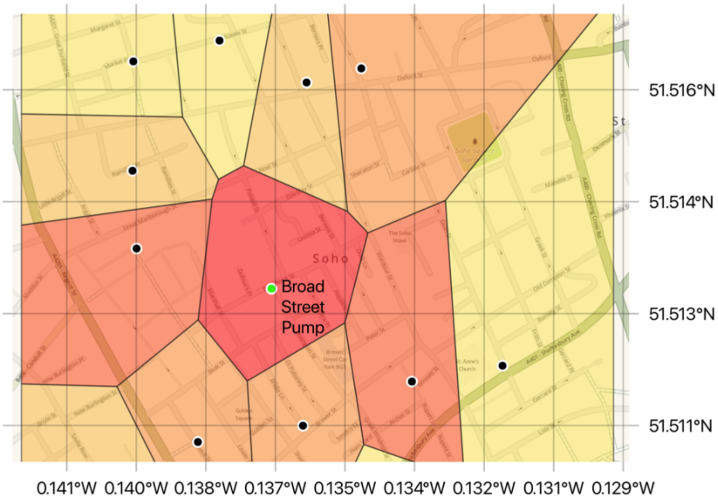
Figure 3: A table showing the number of cholera cases within each region closer to a specific well pump in Soho than to any other.

Area closest to the…	Number of Cholera Cases
Broad Street Pump	309
Upper Rupert Street Pump	75
Carnaby Street Pump	64
Bridle Street Pump	44
Newman Street Pump	41
Warwick Street Pump	17
Berners Street	9
Marlborough Mews Pump	4
Tichborne Street Pump	2
Vico Street Pump	1
Dean Street Pump	1
Castle Street East Pump	1
Oxford Market Pump	0

Question 5: How much higher is the density of cholera cases around the broad street well pump compared to the density of cholera cases in the Poland Street work house? Explain your methodology using the appropriate technical vocabulary (Max. 150 words).

The density of cholera cases in the area around the broad street pump is 13.7 times higher than the density of cases in the Poland Street Workhouse. To measure the density of cholera cases in both areas, I must measure the density of points per unit area of each grid cell. Firstly, I create a raster layer for the point density of cholera cases by creating a heatmap using the 'Kernel density estimation' tool. I then clip the raster layers to mask the polygon vector layers I created for the region closest to the broad street pump than any other and the region containing the Poland Street workhouse. I am then able to use the 'zonal statistics' tool to give me a quantified sum of the density of cholera cases per unit area of each grid cell in both areas.

Question 6: You need to communicate your findings in a clear and impactful way. Use GIS to develop a high-quality map to illustrate your most important findings. Your map must be neat, and easy to read. You must decide which of your GIS layers are most informative, and how to style and present them on your map.



Cholera cases in each region closest to one pump than any other

- 0 - 2
- 2 - 9
- 9 - 44
- 44 - 75
- 75 - 309

Waze (World)

Point_Density_Resampled
Band 1 (Gray)
22.318396
0

Waze (World)