Integrating Geospatial Data

LiDAR, Drones, GPS & CAD for Landfills

With the recent innovations brought about in drone technology, procuring and using digital geospatial data is quickly becoming a necessary and valuable commodity. This paper will look into the geospatial data that is collected and produced for the operation, permitting, tracking, and planning of solid waste sites. This includes technologies such as laser (Lidar) scanning, drone photogrammetry and Lidar, GPS surveying, and digital design files produced in programs like AutoCAD and Microstation. All of these digital data types are important for managing landfill operations and planning activities. However, there is still confusion surrounding digital data and how it can be used. Asset owners, consultants, and service providers all seek clarity about different types of digital data and how they can be used in conjunction with each other and integrated to provide useful information, track metrics and produce deliverables.

Readers will gain a basic understanding of geospatial concepts related to landfills including coordinate systems and the importance of survey control. They will also learn the differences and similarities between data formats and for what they are effectively used for. Finally, we will go over the need for and process of combining data from various vendors and different technologies to produce actionable results.

How Landfills Use Geospatial Data

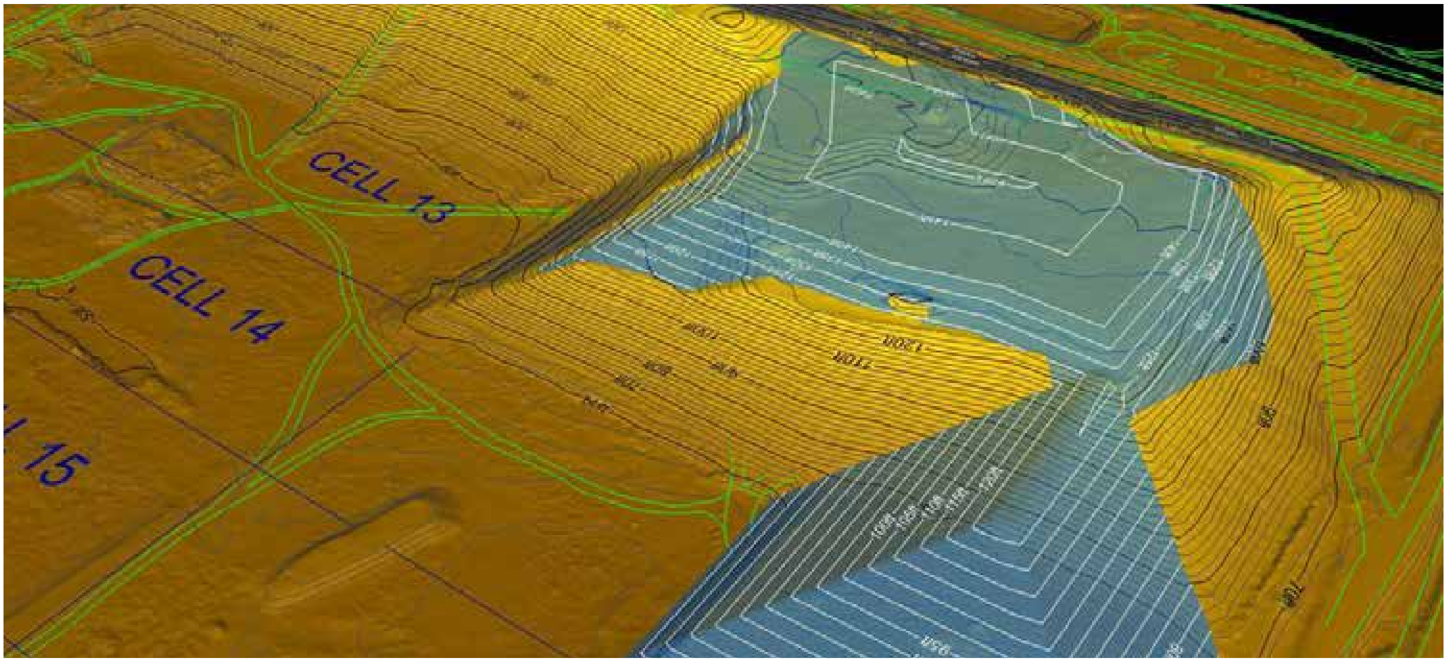
Solid waste sites use geospatial data for many operational and planning tasks. The product being sold at a landfill is the permitted airspace that it has available to fill with solid waste. But in this case, the operation has the ability to increase the amount of product it can sell (airspace) without changing the amount it started with. This is accomplished by setting a target based on the optimal compaction density and then monitoring and making operational adjustments to get as close to that target as possible. It is a widely accepted industry best practice to regularly monitor the compaction density that is being achieved at a site. By setting an optimal density goal that can be achieved at a site for the given environmental conditions, waste characterization and equipment being used, owners and operators can more intelligently monitor the metrics that inform their business decisions.
A landfill is a physical site that is constantly changing. This means that geospatial data must be collected on the surface of the site if we are going to perform tracking, managing, projection, and planning tasks

that are affected by the size, shape, and height of the site. Tracking the physical characteristics of a site allows us to make sure the site is adhering to permit requirements like maximum elevations, side slope angles, waste footprints, and boundaries of different waste types. A single point can tell you the elevation for a given coordinate, and two points can tell you the slope of a sidewall. But a complete 3D surface can tell you where you might be overfilling or under-filling, where there might be an abnormal amount of settlement that can be a sign of sub-surface problems and is a way to identify sloughing and bulging.

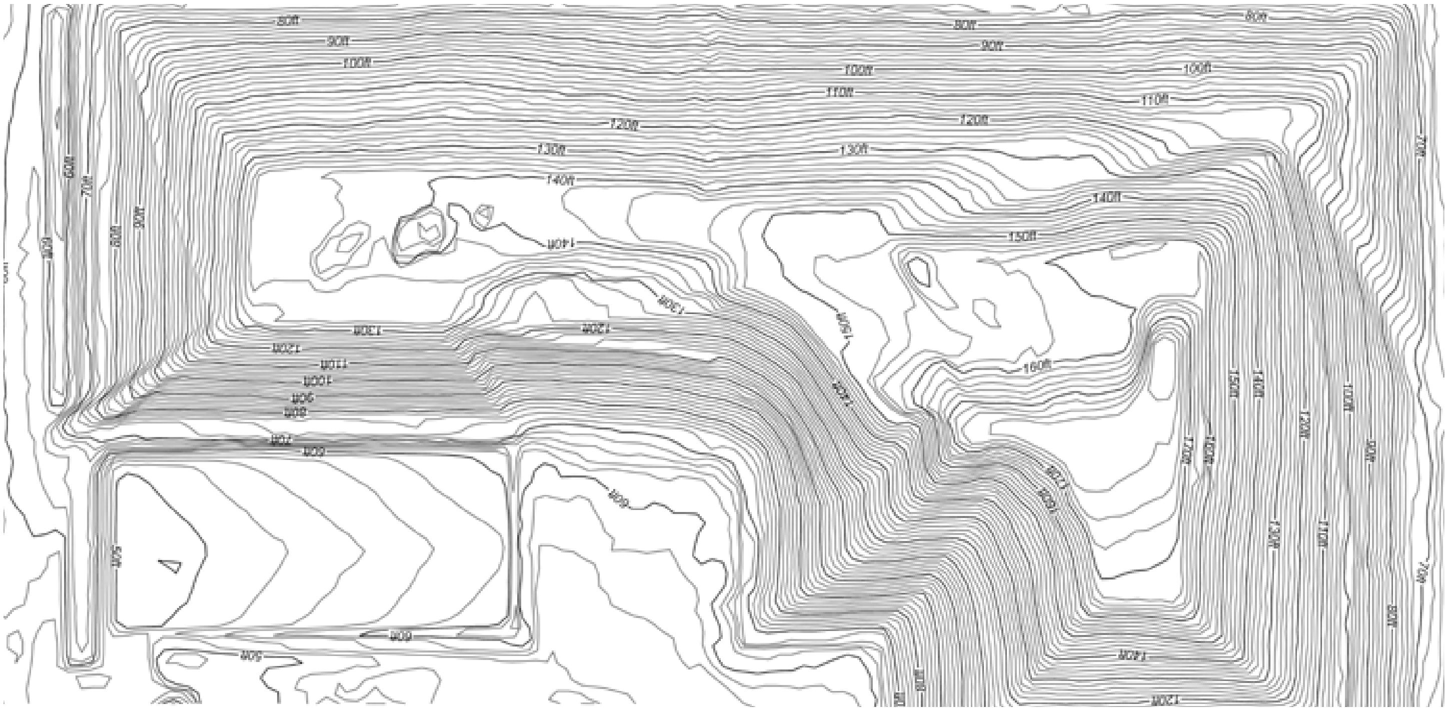
What is Digital Data?

For simplicity, this paper uses terms that are common to the places and types of work we are involved in. So even though there are many ways to describe something, you'll see specific terms like State Plane, Laser, and Feet, instead of other specific or more general terms. Geospatial data can be one of many types of datasets that has geographic coordinates that relate to the earth and whose coordinates describe an object or feature in the physical world. Geospatial data can be collected by measurement instruments like GPS receivers, total stations, laser scanners or photogrammetry.

The simplest form of data is a single point that we know the location of, both horizontally and vertically, relative to a defined coordinate system. This means that you could have multiple people using different equipment and different processes independently measure that point and they would all come up with something close to the same answer. If you connect two points then you get a line, multiple lines and you get a polygon or facet, multiple facets and you have a surface or triangulated irregular network (TIN). Now the data is starting to take shape, and it is actually beginning to look like the object or feature that it was measured from.



Modern data collection tools like laser scanners and drones generate files containing millions and millions of geospatial points; these are almost always referred to as "point clouds." Since these technologies capture data indiscriminately, they end up recording points on everything they are pointed towards, like buildings, trees, and cars, as well as the earth's surface. This extreme detail is well suited for identifying the locations and dimensions of structures and objects. For bulk material purposes such as solid waste landfills, we are usually interested in the points that have hit the natural ground or the bare earth. This bare earth model is used to generate most deliverables including digital contours, breaklines, spot elevations, and various volumetric calculations.



Processing, viewing, and manipulating high resolution point clouds is still a fairly specialized task that requires purpose-built software that can handle and display the millions of data points. This capability was pretty rare in most mainstream software just a few years ago, but it is becoming more common today. The big software companies have embraced the trend toward high resolution data, with most now supporting the viewing and manipulating of point clouds. There are some free viewers that can be downloaded that allow you to open point clouds in a 3D environment where the data can be zoomed, rotated, panned, colored by elevation, and they allow some simple measurements like distance, angle, and area. The next phase of software is cloud-based portal programs that allow you to view, manipulate, and process data without having to download and install the software, or even the data files themselves, on your computer. Instead, everything is hosted on cloud-based servers and your local machine just becomes a gateway to display the information.

Once collected, this point cloud data can be used for gathering information and insights beyond its original purpose. It is essentially a high-resolution record of the existing conditions on the site. Aside from the current topography, there is information like equipment, building and vehicle locations, terrain slopes, water levels, utility pole locations and if photogrammetry is used, a current orthophoto.

Coordinate Systems & Survey Control

One of the keys to integrating data between different service providers is to understand the coordinate system and control network at a landfill. The most basic question is whether the site is on a local or global coordinate system. A local system is one where an arbitrary point has been chosen to create a benchmark on or near the site and is assigned a set of coordinates like an Easting of 50,000 ft and Northing of 50,000 ft. Then all of the coordinates on the site are measured relative to that benchmark, but they have no meaning when compared to anything off the site.

A global coordinate system is one that has well-defined parameters that are known and published. Another trait of a global coordinate system is that it is relevant across different sites and different regions. Measurements in a global coordinate system can be repeated by separate, independent people with no prior knowledge of the site, except for what coordinate system is used.

For any type of geospatial data to be used in conjunction with other data, it's critical that it all references the same coordinate system that is used for that site. Not only that, but even if a global coordinate system is being used, it is still necessary to "localize" the data to that specific site. Some sites are based on a global coordinate system but also have a horizontal or vertical shift. To make sure that data is tied correctly to a site we need to know three things: 1) the coordinate system being used, like local or NAD83 State Plane, 2) where a physical benchmark or control point is on the ground and 3) what the known coordinates of that point are. If we know these three things, then mapping service providers, surveyors engineers, contractors, and consultants should all be able to produce their work in such a way that it integrates or "lines up" with all the other work being done on the site. Whether the work is design slopes, as-built conditions, current topography or grading elevations, the location information that is contained in that work is in one way or another referenced back to that point on the ground with agreed upon coordinates. For the sake of accuracy and consistency, it is more important than ever to have and maintain a site benchmark or control network with known coordinates.

Depending on the type of equipment being used to collect data, there are different ways to localize it to a site's specific global or local coordinate system. The first is real time kinematic (RTK), this is where a base station is set up over a known point and the correct coordinates are entered into it. Then the "rover" equipment, like a drone, laser scanner or GPS receiver, receives live information from the base station that corrects the rover position as it records data. There is another type of RTK correction called virtual reference station (VRS). With a VRS system, the rover equipment is not communicating with a base station that is set up on site. Instead, the corrections are calculated by a network of base stations in the area that are constantly running and delivered over a cellular network. Some limitations of using a VRS network are that the data is not being tied directly to the known local control point, which could result in some positioning errors and that the rover must maintain a live connection to the cellular network during data collection.

Data files can also be corrected and localized after the original raw data is collected by using a log file from GPS equipment that was recording at the same time the data was being collected. This is called post processed kinematics (PPK). Performing PPK corrections is usually very reliable and accurate. The last common method for correcting geospatial data relates to the use of photogrammetry or data derived from camera images.

When a site is modeled using imagery, then you have the added benefit of being able to see actual physical objects on the ground. If these objects that can be seen in the photos are some type of target with a clear center and if you know the exact coordinates of that center, then you can use those known targets to position and scale the data correctly. These are traditionally known as aerial targets or aerial panels when they are flown by manned airplanes and ground control points (GCPs) when they are flown by drones.

How do Drones Fit?

A drone (UAV, UAS, etc.) can be a fantastic tool for capturing geospatial data. The equipment and workflow of flying drones for mapping is different from what has been done in the past, but in the end, we are looking for products that can be used reliably for the same planning, designing, and operating purposes as before. So even though the technology is new and ever-changing, the same traditional best practices that were discussed earlier must be understood and followed to produce results that are professionally acceptable.

Modern drones can be equipped with either cameras that collect regular images (photogrammetry) or can carry laser scanners (Lidar), both of which are used to map existing topography. Camera-based drones are usually much cheaper, lighter, and easier to operate than lidar drones. They also have the benefit of collecting aerial imagery as part of the normal workflow. This means that you get both topographic data and a current aerial orthophoto, sometimes called an orthomosaic, from the day of the flight. Because they rely on images, weather and lighting conditions can have a serious impact on the quality and efficiency of drone flights that use cameras.

Lidar drones are more expensive and more complex to operate, but they provide some very valuable benefits over image-based drones. The ability of lasers to capture points is not affected by lighting conditions, so Lidar can technically be performed in complete darkness, without any negative impacts on the resulting 3D data. Unlike photogrammetry, Lidar is excellent at penetrating dense tree canopies and other highly vegetated areas. Camera-based systems that rely on photos do a very poor job at finding and recording the very small spaces between branches and leaves to reach the ground below. What you usually get is a layer of data that is “draped” over the area like a sheet laying over the top of the trees. A laser scanner on the other hand produces an extremely high resolution of points on the ground and the beams of light themselves are each so small that the laser pulses can fit through those tiny spaces in the vegetation and hit the ground below. Another characteristic of aerial Lidar, known as multiple returns, occurs when part of a single laser pulse hits an object like a branch or leaf and the rest of the pulse continues on to hit something else like the ground.

Depending on the type of Lidar system being used, the complete final point cloud could be ready immediately for filtering, modeling, and measurements. Other systems require some amount of post processing of the data to incorporate a survey control network or to correct the position and orientation of the drone before the final point cloud is created. One of the main drawbacks to using Lidar instead of photogrammetry is that when only a laser is used then there are no photographs taken to create an aerial orthophoto. There are some drone systems that have both a Lidar unit capturing data and a camera collecting imagery at the same time. That scenario makes it possible to generate an orthophoto and to colorize the point cloud with true RGB color values from the photos that are taken.

What Data Should Be Integrated? All of it.

The end goal is that any digital data that is collected or created for a site can be used in conjunction with any other data from that site. This is true regardless of who is doing the work, all professional service providers should have a clear understanding of what it takes to accomplish this and be able to produce data that is geospatially localized to that specific site. Below are some of examples of the types of files, products and deliverables that should be able to be used together:

- **Aerial Surveys (Drone, Photogrammetry, LiDAR)**
  - Point clouds
  - Orthophotos
  - Contours
  - Breaklines
  - Spot Elevations

- **GPS Ground Surveys**
  - Grade staking
  - Survey points files
  - Protective cover certification survey

- **Design CAD**
  - From consultants, surveyors, designers
  - Protective cover design
  - Intermediate grades (constructed remaining airspace)
  - Final top of waste grades (overfill monitoring)

Integrating these various types of data will give operators a better overall understanding of their sites. They can then use this information to improve their decision-making and overall operational efficiencies. As we have discussed in this paper, in order to integrate these various types of data and get the most out of your data, you need to understand and use proper techniques. There are many tools to collect and process the data, but in order to get true value from it – the insights and business intelligence – you need to be able to integrate all of your site data.

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