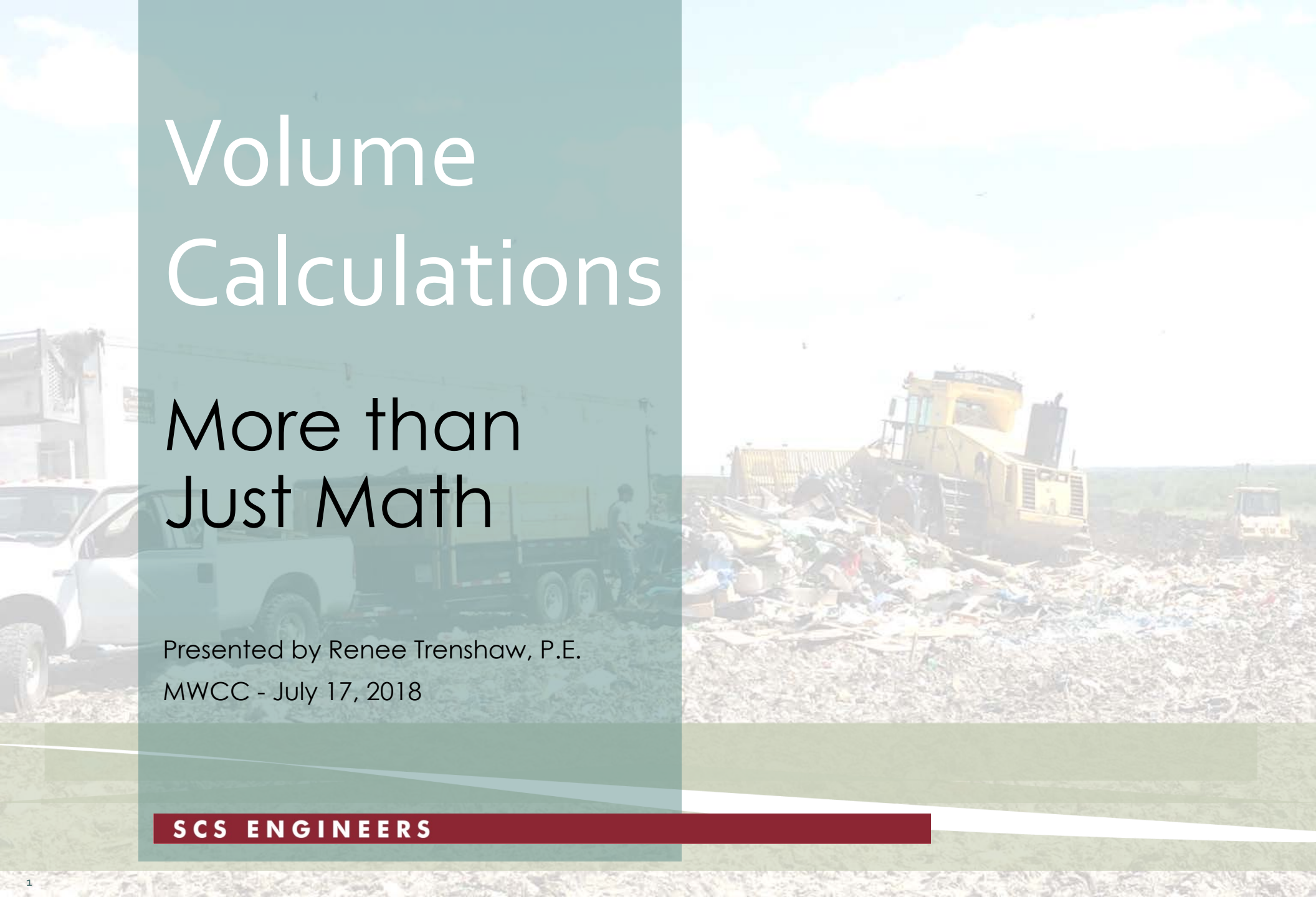

Volume Calculations

More than Just Math

Presented by Renee Trenshaw, P.E.

MWCC - July 17, 2018

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Overview

- Use
- Methodology
- Critical Components
- Scenarios

Their Use

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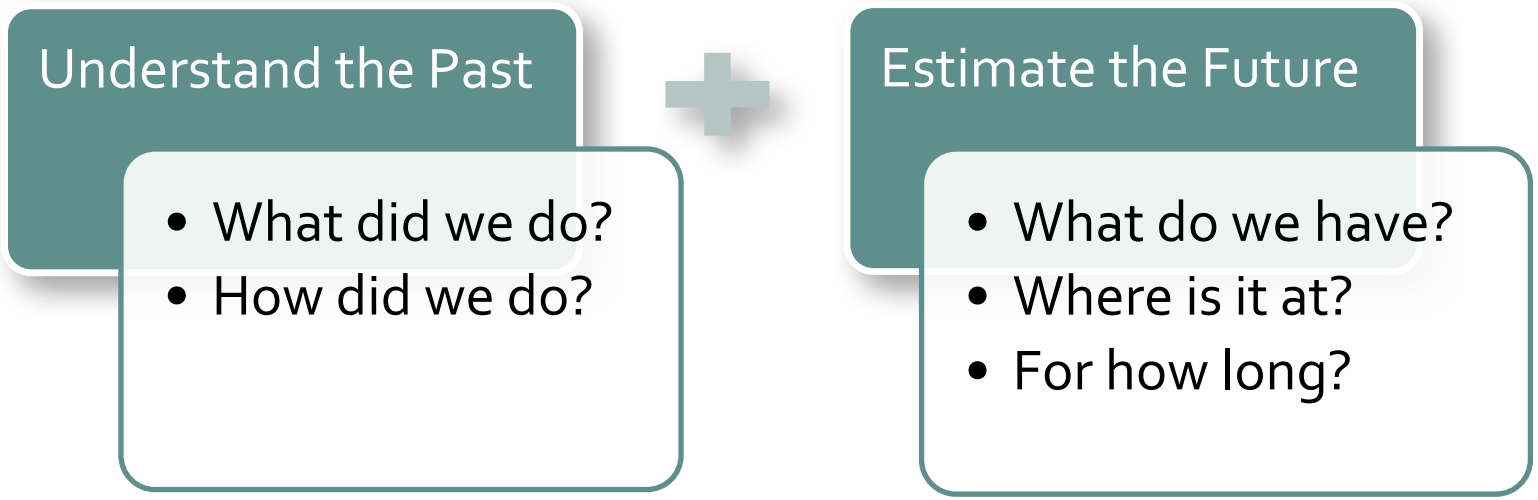
Two Big Reasons



- The need and use varies:
  - By Client
  - By State
  - By Consultant

Example Uses

Estimate the Future

- Airspace available
- Soil available
- Construction phasing and timing
- Permitting
- Regulatory compliance
- Planning (e.g. site, state)
- Lifespan estimate
- Asset evaluation
- Operations

Understand the Past

- Airspace used
- Soil used
- Operational performance metrics (density)

Can help answer questions

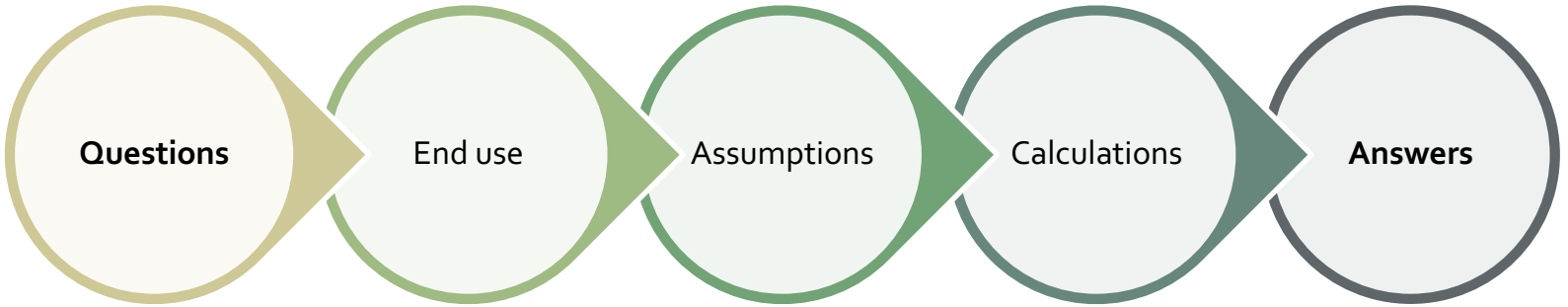
- How much capacity does my landfill have?
- How much airspace have I used?
- How long until the landfill fills up?
- How much material did we take in today?
- How well are we utilizing airspace?
- When will we run out of airspace in this cell?
- Where can I put waste when it rains?
- How long until we need to construct the next cell?
- How much dirt do I need to cover that area?
- How much dirt will I get if I excavate that area?
- How many trucks will I need to haul that dirt?
- How big does my berm need to be to water?
- Can my pond handle the storm?
- How much is my landfill worth?

…and the list goes on.

…but to answer questions

(correctly)

- Must know the end use of volume calculations.
  - Guides assumptions during the calculation phase.



Methodology

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Volume

- Volumes are:
  - Comprised of three dimensions
  - Measured in cubic units
- Calculate by hand
  - Formulas for different shapes
- Computer Aided Drafting
  - CAD
  - Compare two 3D surfaces

Typical Units:

- **Cubic meters (m^3)**
- **Cubic feet (ft^3)**
- **Cubic yards (yd^3 or cy)**
  - **1 cy = 27 ft^3**

Critical Components

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The Inputs

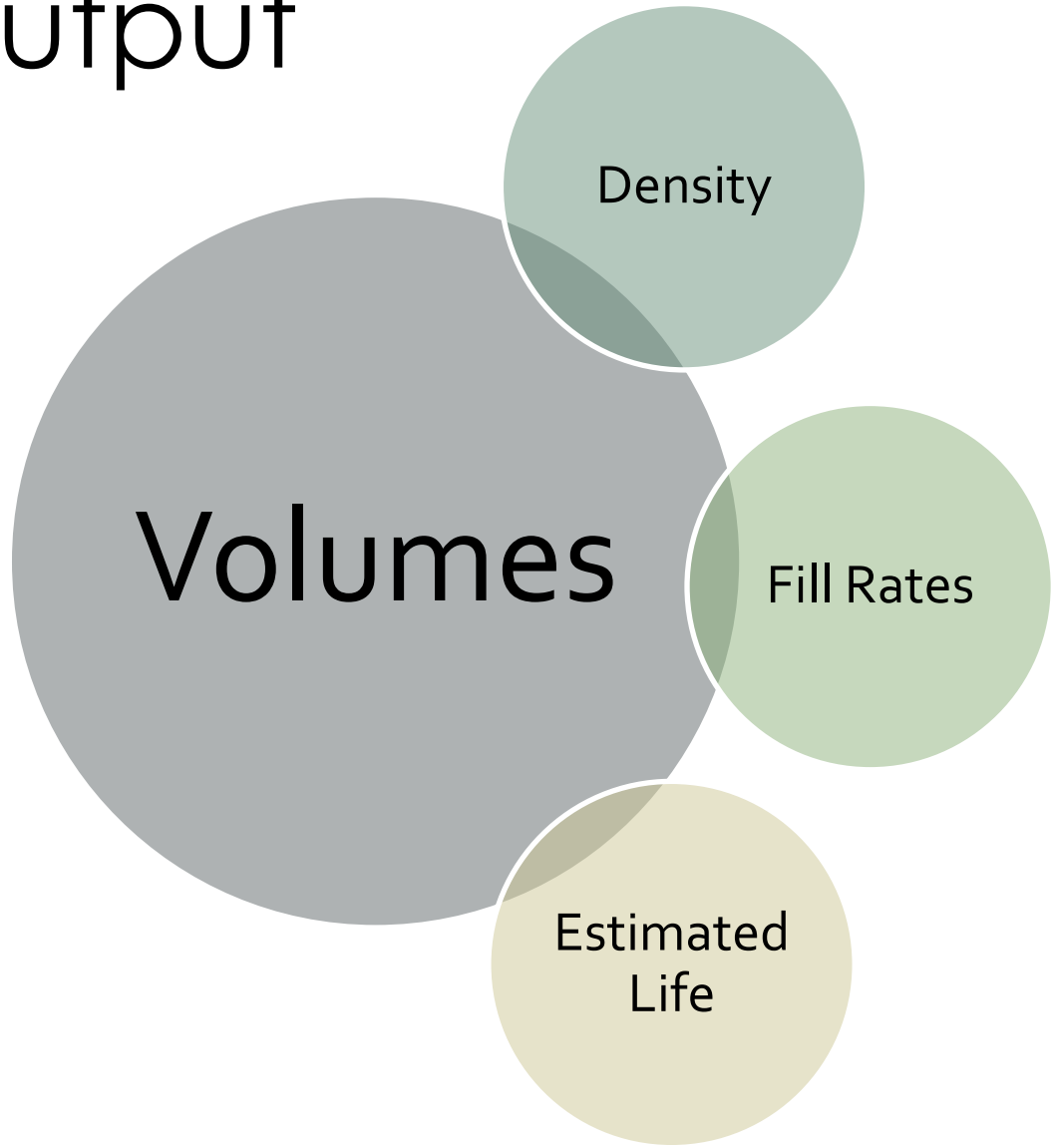
Surface Grades

- Topography (existing)
- Permitted (base, cover, and slopes)
- Operational (intermediate and existing waste slopes)

Boundary

- Edge of waste
- Active/primary fill area
- Permitted
- Constructed
- Borrow source

The Output



Density / Specific Weight

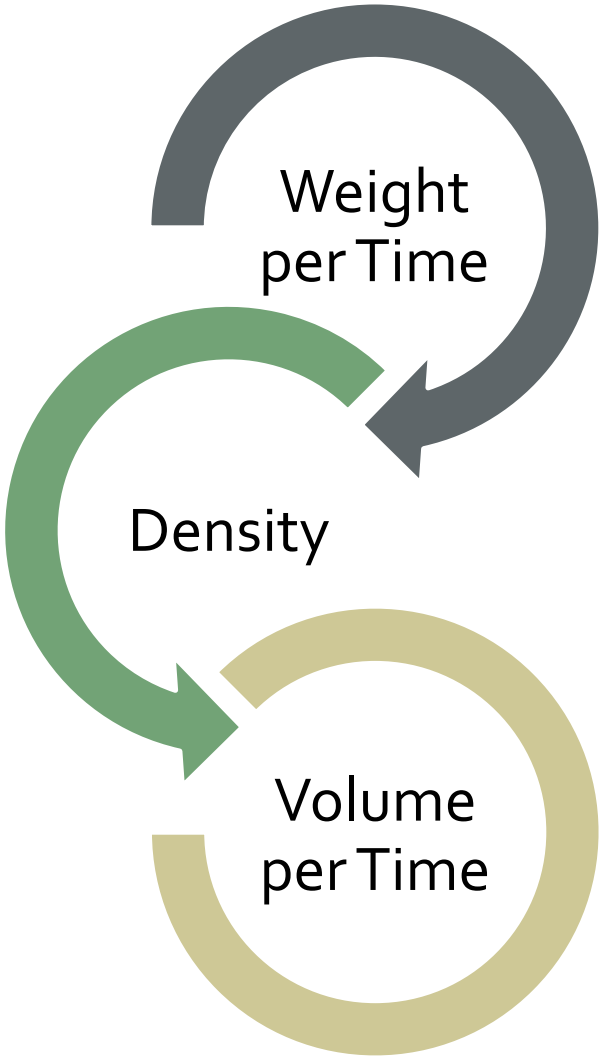
- Density is:
  - Mass divided by volume
  - **Weight divided by volume (specific weight)**
  - Measured in:
    - **Pounds per cubic foot (lb/ft^3)**
    - Pounds per cubic yard (lb/yd^3)
    - Tons per cubic yard (ton/yd^3)

- Can include:
  - Waste
  - Soil
  - Waste and soil

Technically we use specific weight but loosely call it density

Fill Rates

- Weight per time
  - Tons per day (tons/day, tpd)
- Volume per time
  - Cubic yards per day (cy/day)
  - Cubic yards per month (cy/mo)
  - Cubic yards per year (cy/yr)
- Density allows you to move between the two
  - Consider the density type
    - Waste, soil, or waste and soil



Remaining Life Estimates

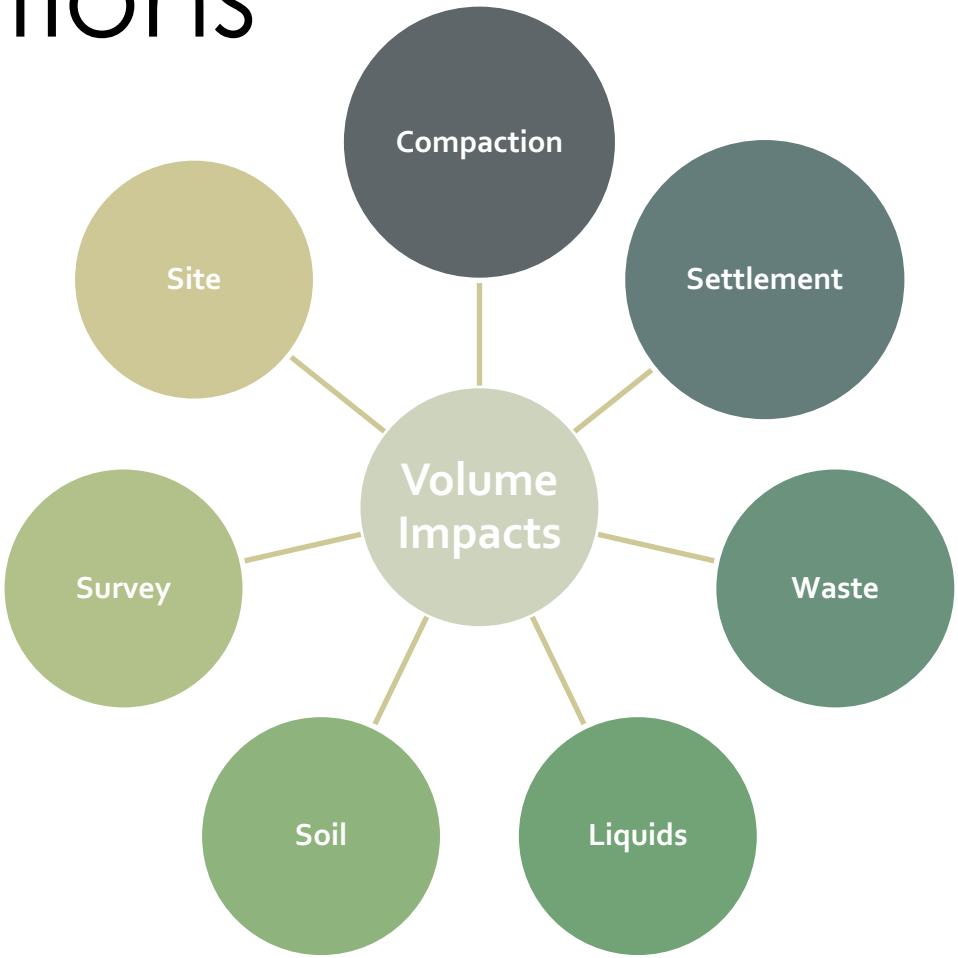
- Projection of how long landfill will last
- Different methodologies
  - Based on inputs and assumptions

Sensitive to inputs with future predictions

- Always need:
  - Volume airspace remaining
- May need:
  - Density (projected, varies)
  - Volume to be consumed (projected, varies)
  - Tonnage (historical)

Other Considerations

- Compaction methods
- Settlement and compression
- Waste type and composition
  - Compressible
  - Degradable
- Liquids addition or removal
  - Bioreactor
  - Leachate recirculation
- Soil
  - Waste to soil ratio
  - Soil types
  - Soil removal
  - Alternative daily cover
- Survey accuracy and precision, type
- Site facilities, roads, stockpiles, slope repair



The Fun Examples

And a little math.

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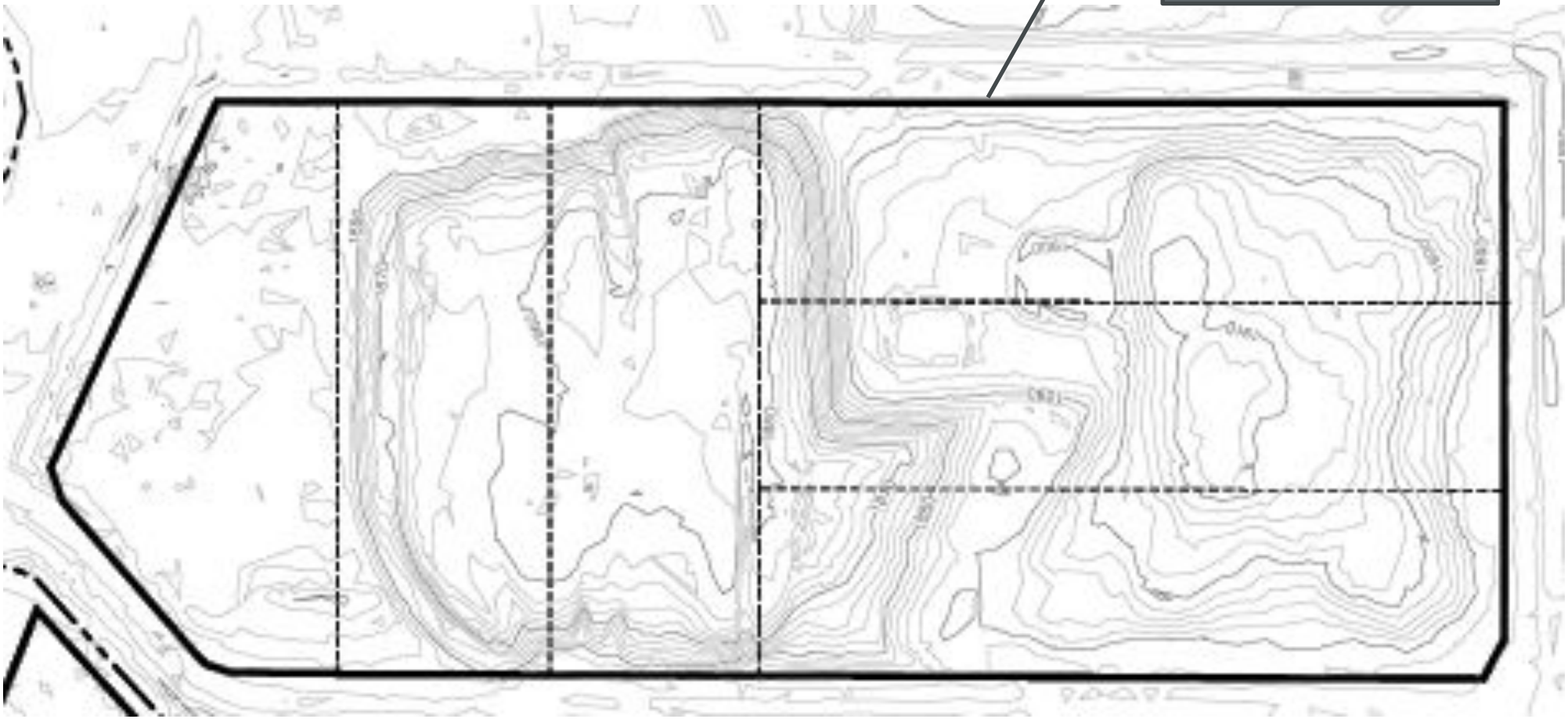
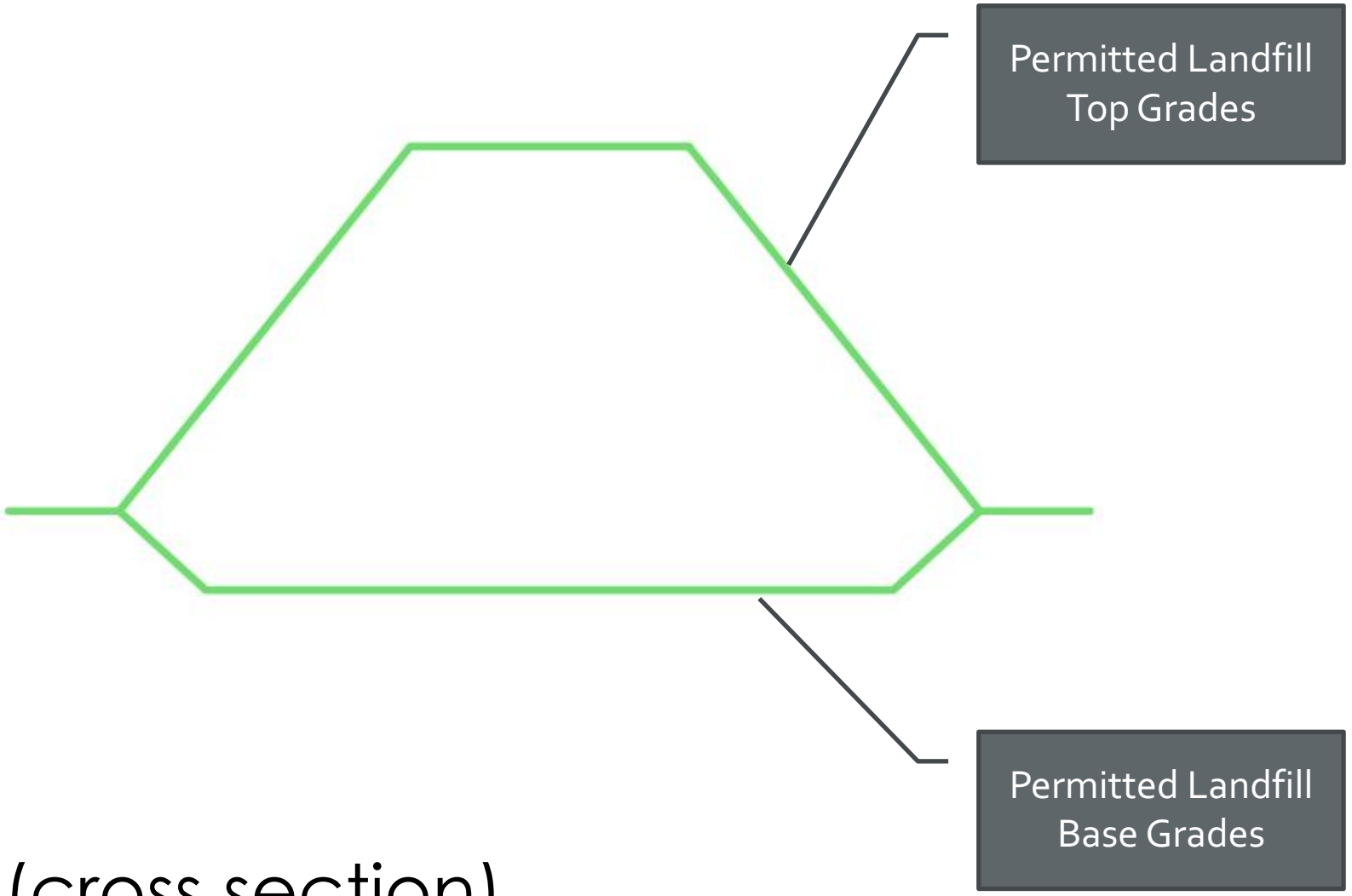
Example General Info

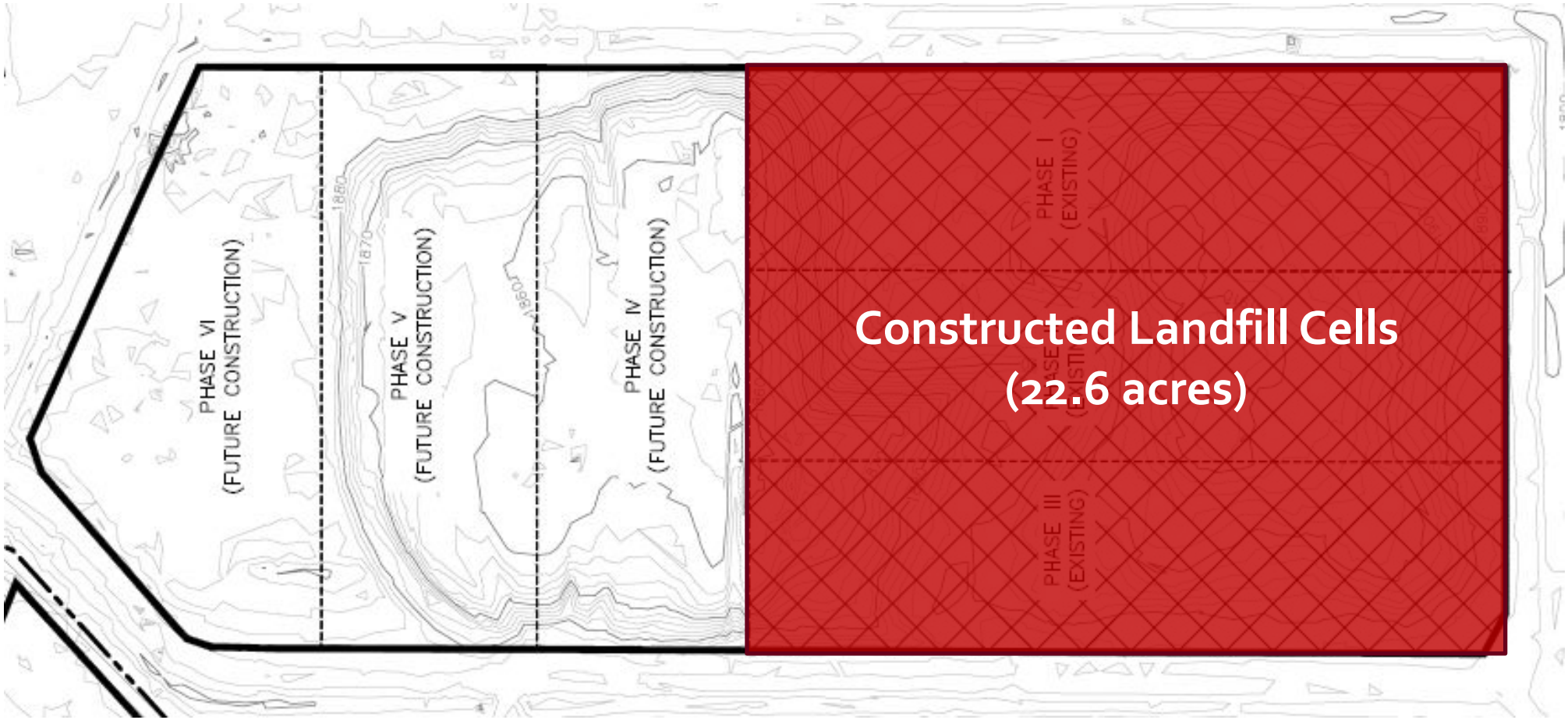
- Focus on CAD
  - (not hand calculations)
- Utilized AutoCAD Civil 3D software
- CAD Volume Surface
  - Surface 1 = the bottom surface
  - Surface 2 = the comparison surface

The Site (a landfill)

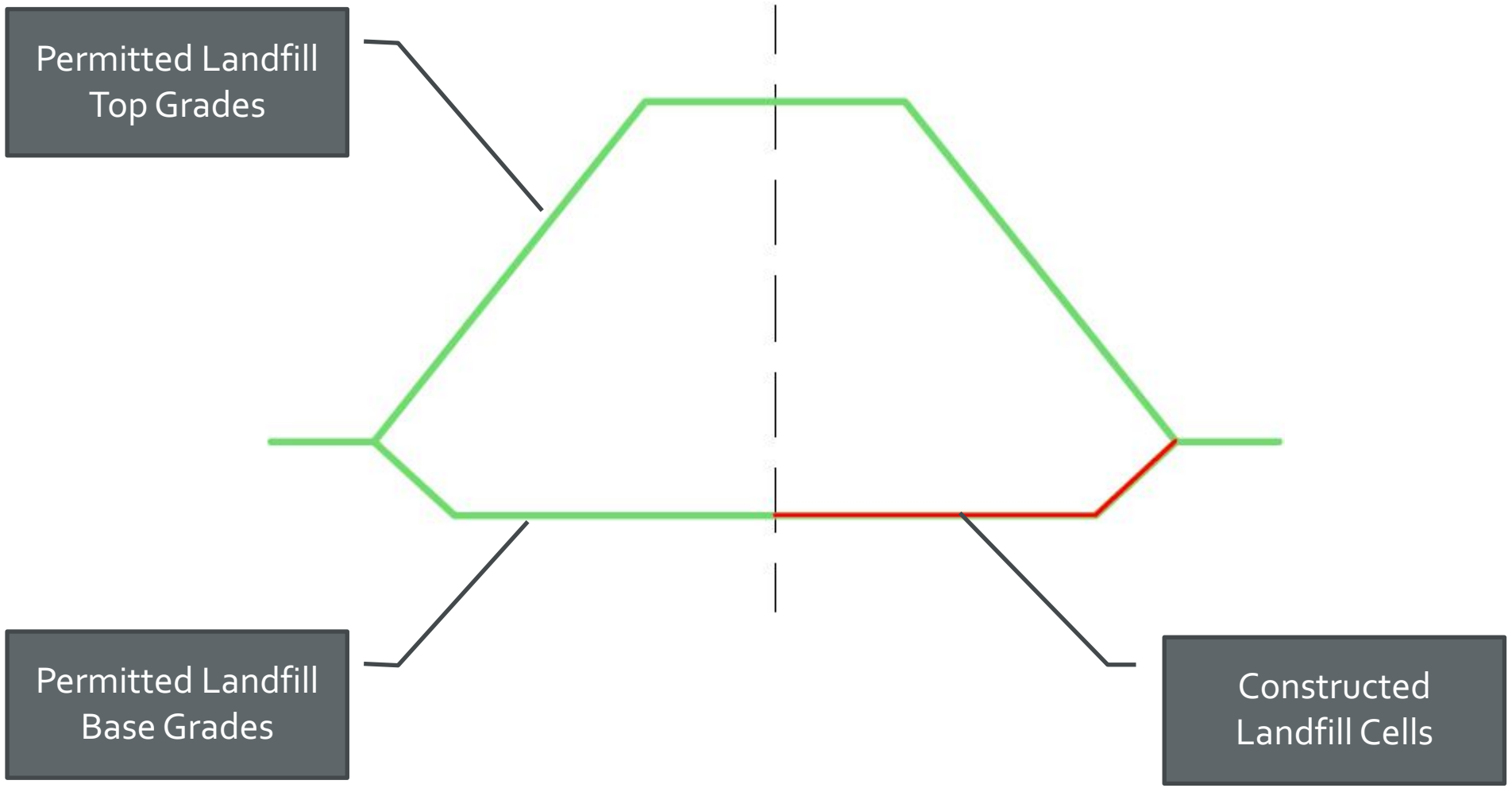




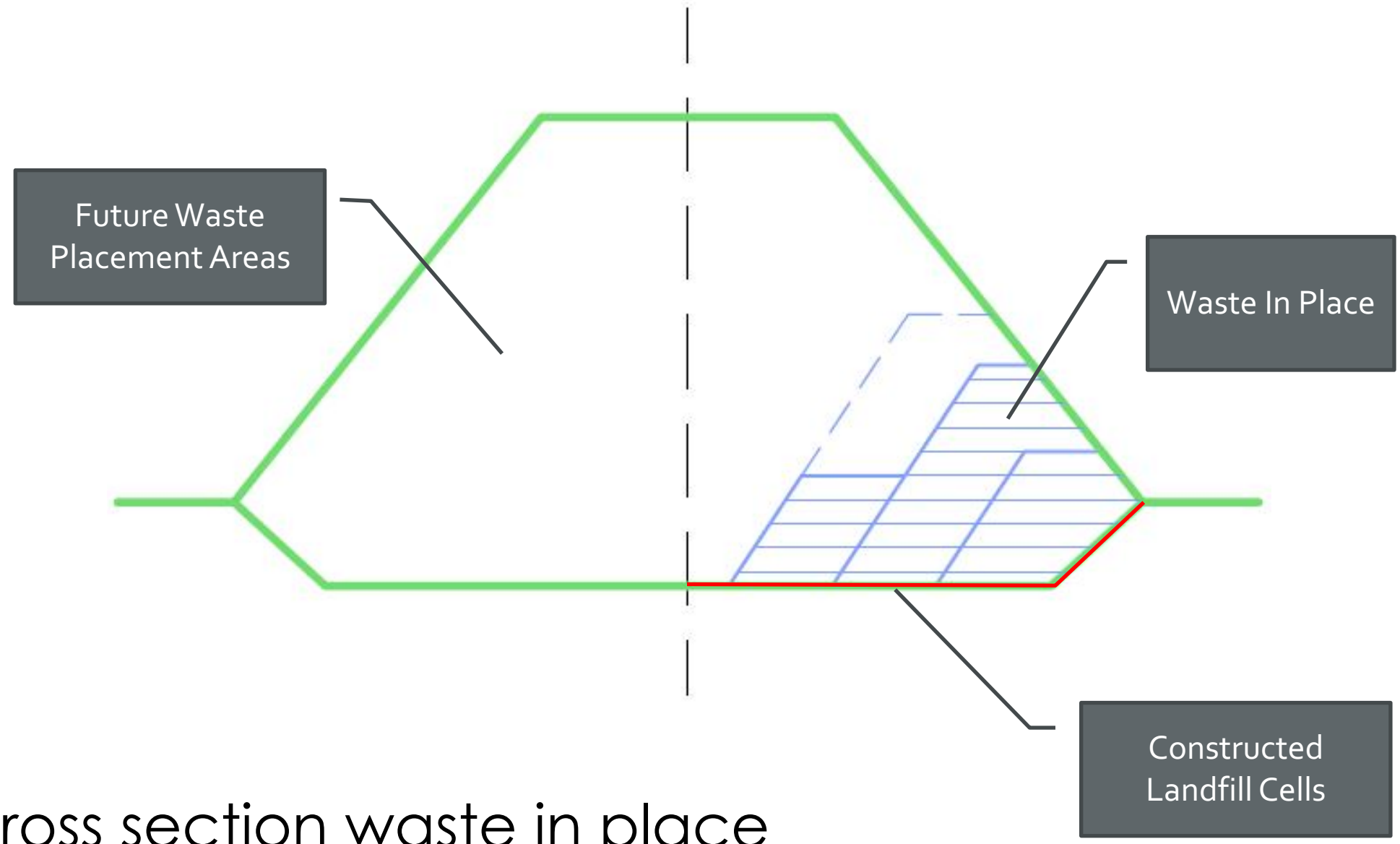
The Site (cross section)



Landfill's Constructed Area



Cross section with constructed area



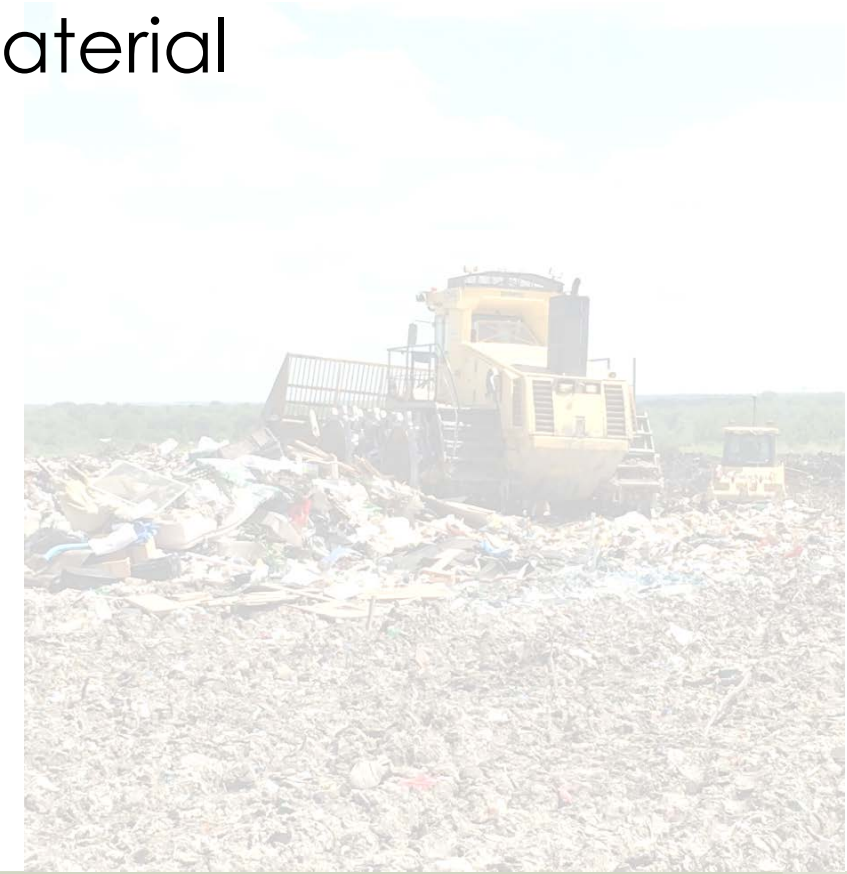
Cross section waste in place

Site Information

- MSW Landfill
  - 41.5 acres permitted
  - 22.6 acres constructed
- Permitted capacity
  - 3,240,000 cy
- Remaining permitted capacity (2017)
  - 2,233,000 cy
- Remaining constructed capacity (2017)
  - 597,900 cy
- Old survey completed in 2017 (ground survey)
- New survey completed in 2018 (drone survey)

Some Typical Questions

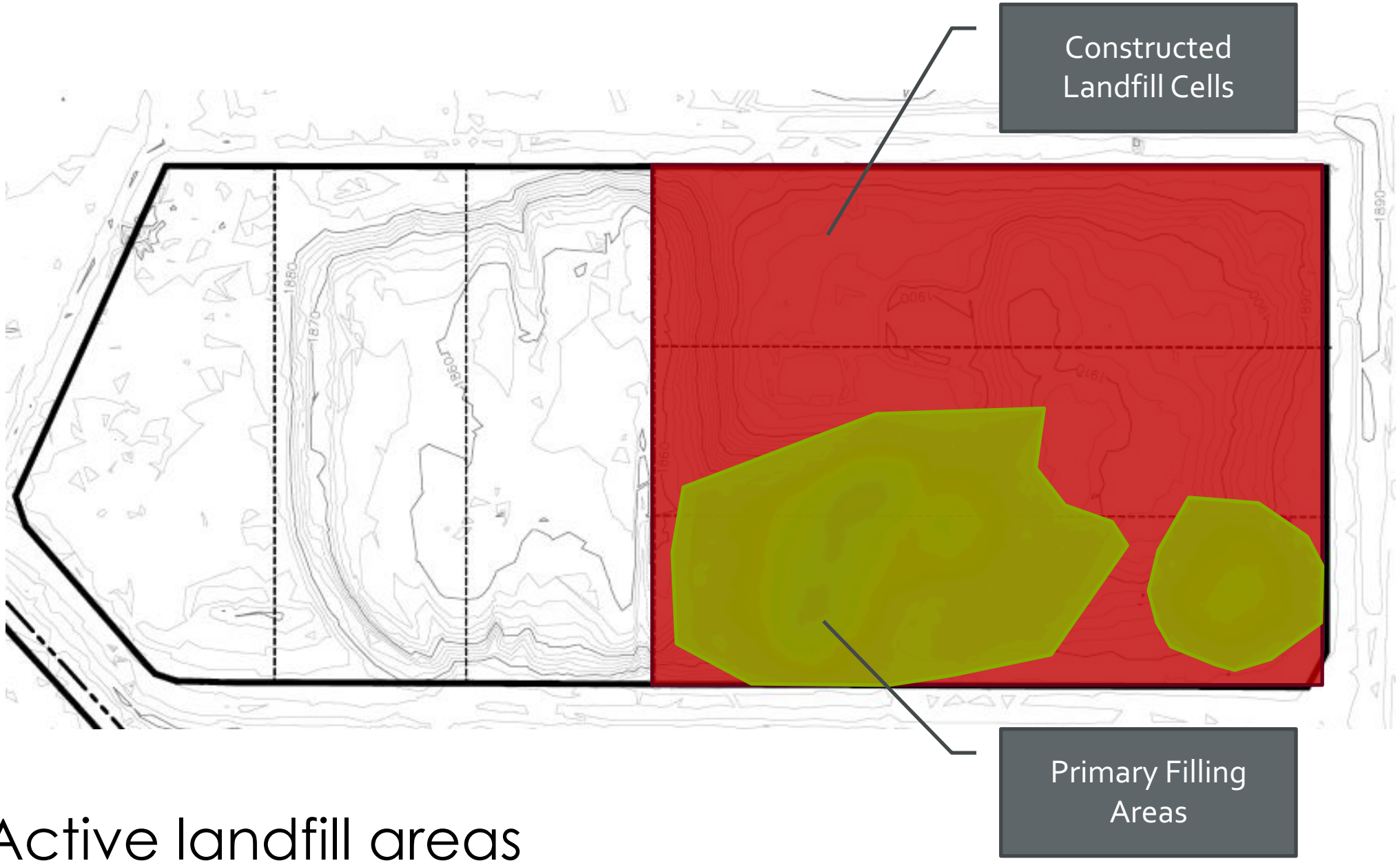
- How much airspace consumed between surveys?
- What is the density of the material in place (lb/cy)
- How long will landfill last?
- Survey impacts?



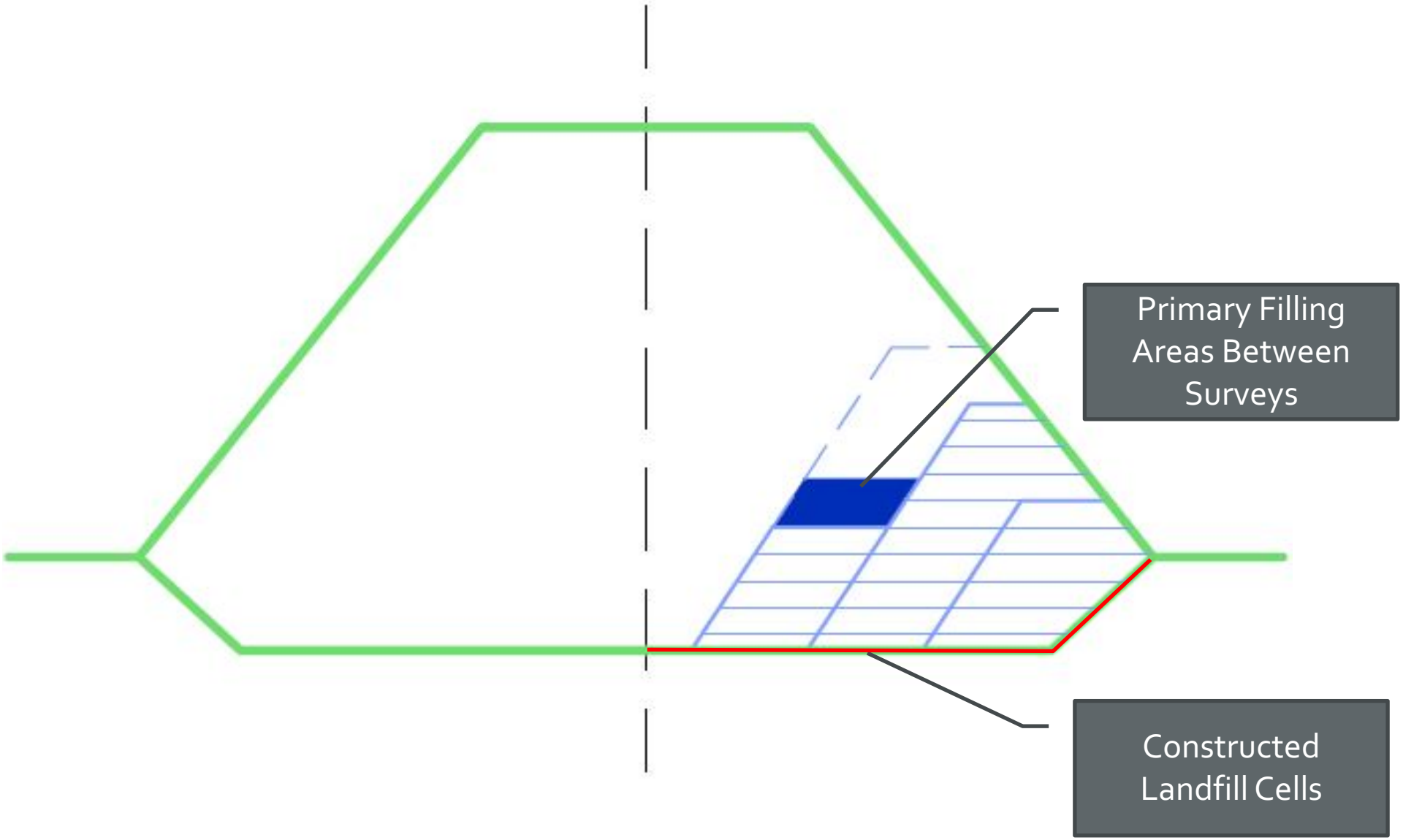
Airspace Consumed between Survey Dates

	Scenario 1	Scenario 2	Difference
Surface 1	2017 Survey	2017 Survey	
Surface 2	2018 Survey	2018 Survey	
Boundary	*Constructed Footprint*	*Primary Filling Area*	← *Variable*
Airspace Consumed	**73,000 cy**	**62,000 cy**	**11,000 cy**
Tonnage	33,569 tons	33,569 tons	
Density	**920 lb/cy**	**1,083 lb/cy**	**163 lb/cy**

What does this tell you?
How would you use each?



Active landfill areas



Cross section with active filling area

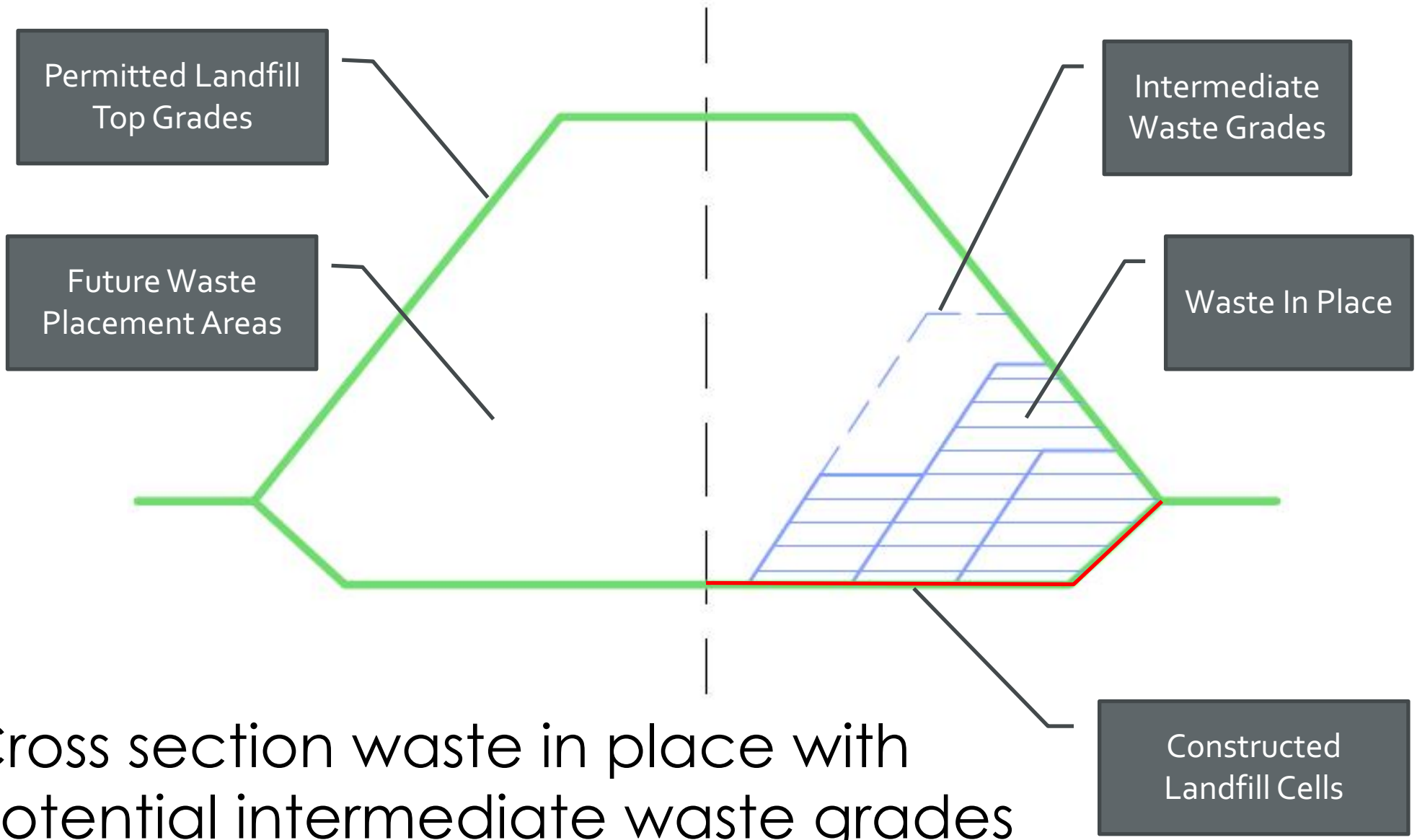
Things to consider:

- Constructed landfill footprint boundary
  - Accounts for landfill as a whole
  - Includes some settlement outside areas where no change occurred (not quantifiable)
- Primary filling area boundary
  - Better gauge of operational metrics
    - How are we filling?
    - How well are we utilizing soil?
    - Etc.
- **Volume notably impacts density numbers**

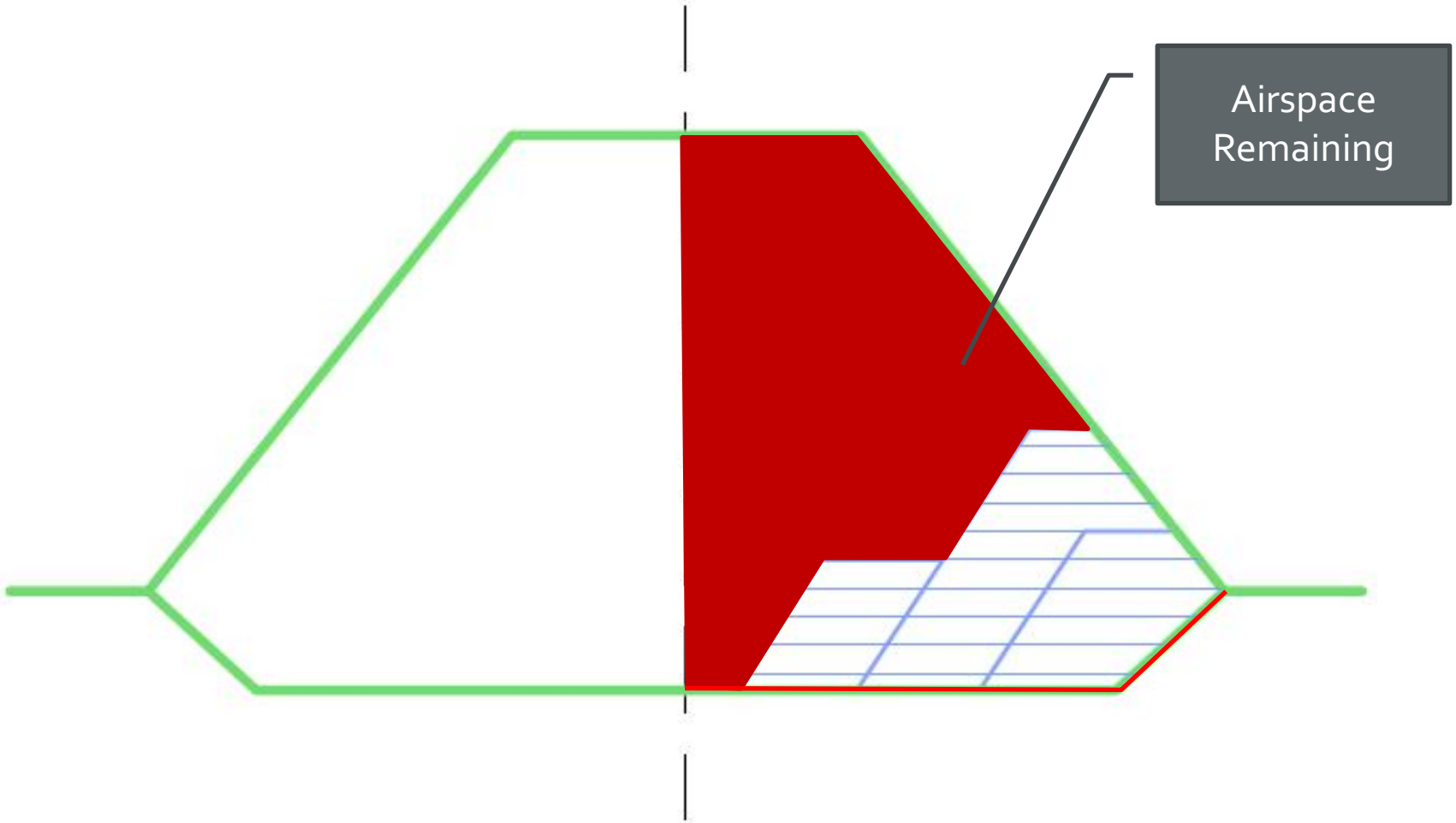
Airspace Remaining in Constructed Landfill Cells

	Scenario 1	Scenario 2	Scenario 3
Surface 1	2018 Survey	2018 Survey	2018 Survey
Surface 2	*Final grades*	*Intermediate grades*	*Intermediate grades, revised*
Boundary	Constructed Footprint	Constructed footprint	Constructed footprint, revised
Airspace Remaining	**548,000 cy**	**527,000 cy**	**515,000 cy**

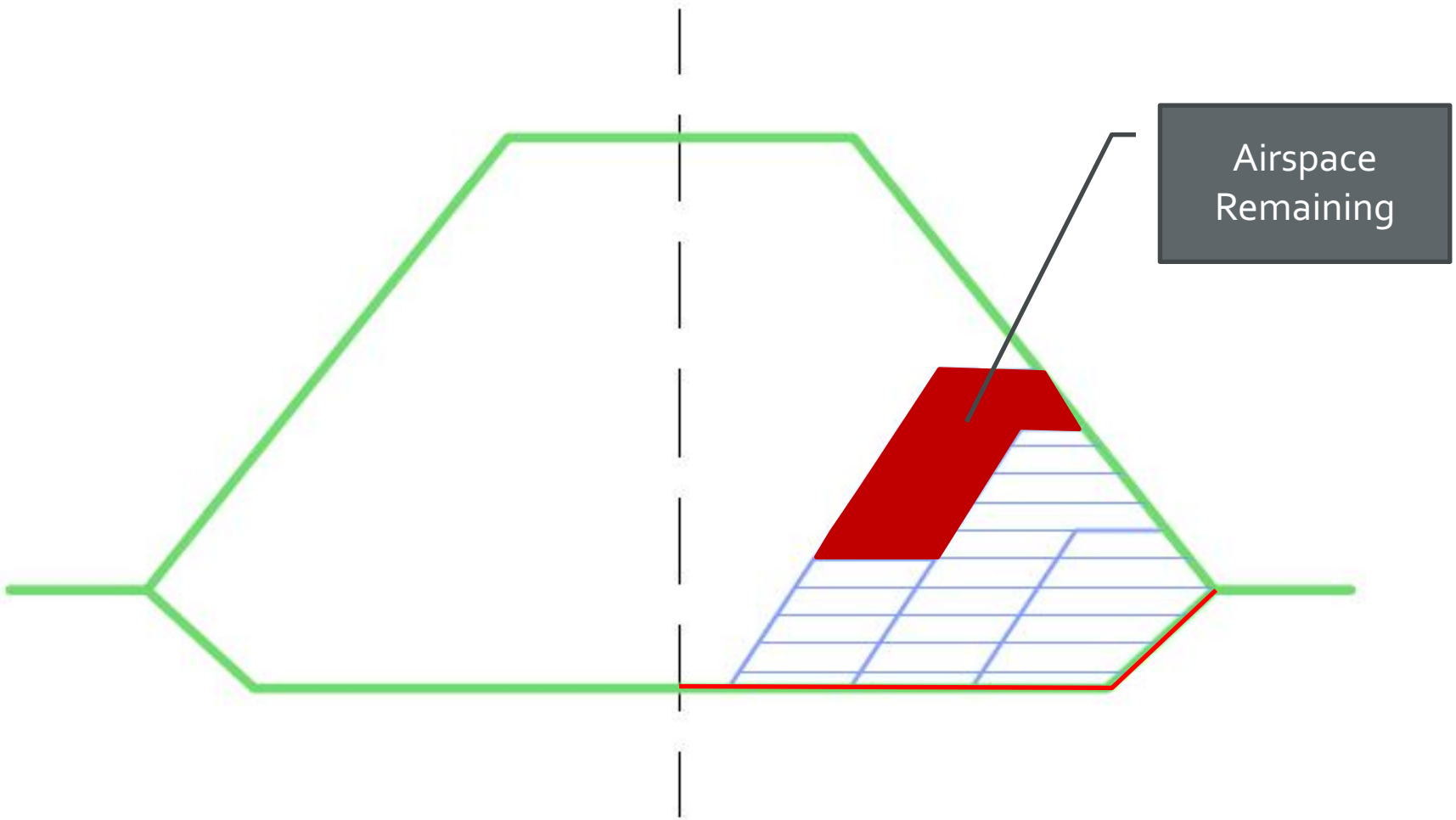
What does this tell you?



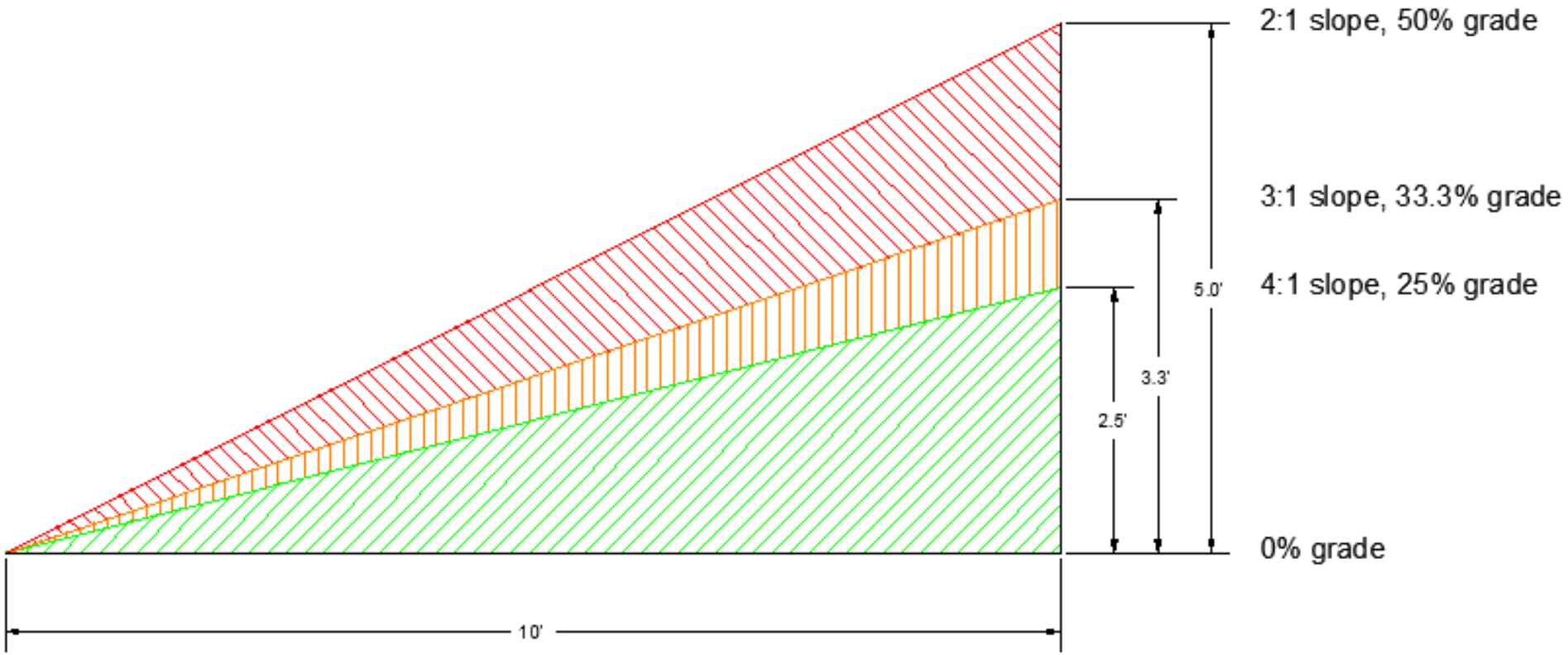
Cross section waste in place with potential intermediate waste grades



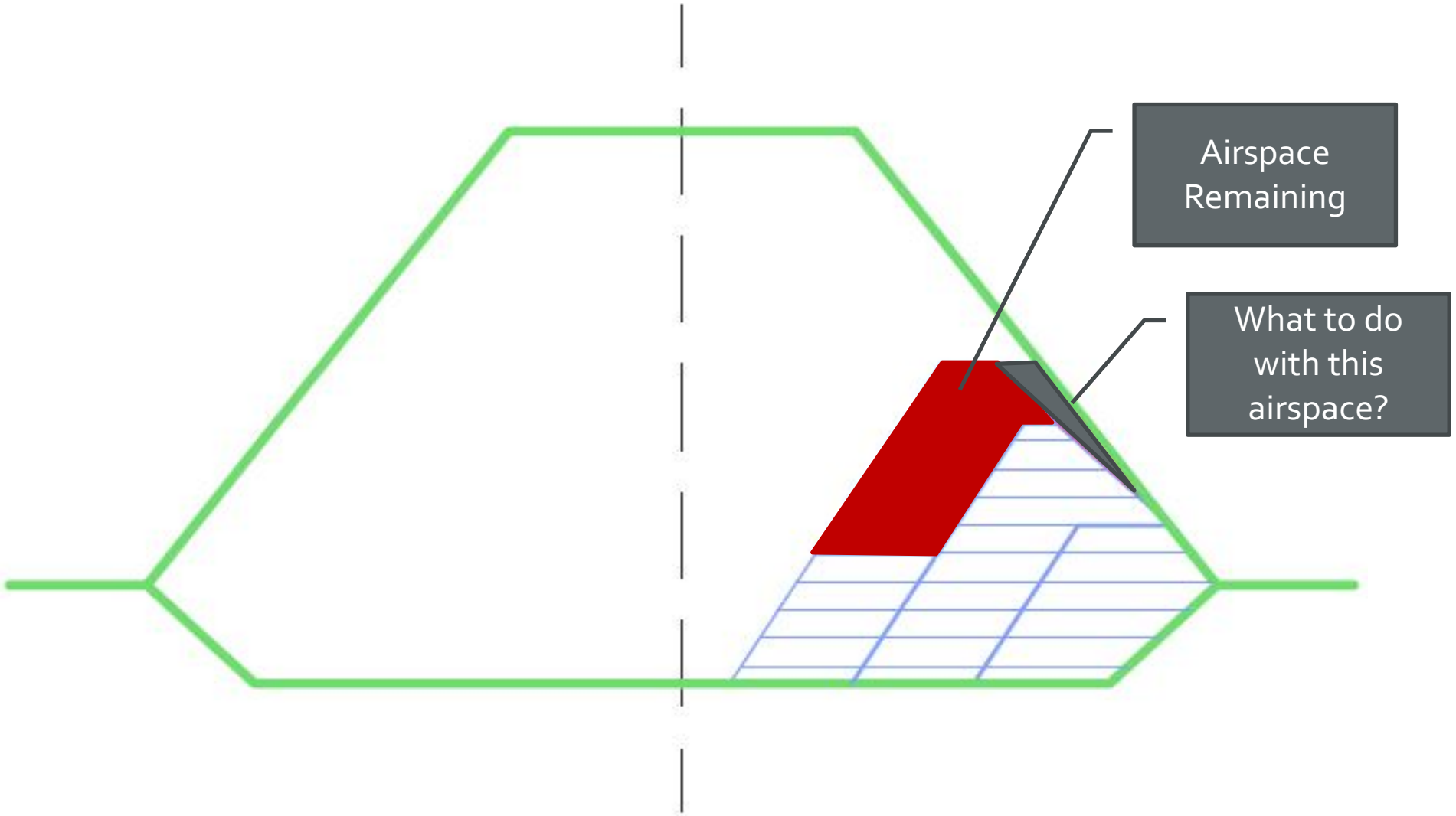
Scenario 1



Scenario 2



Impacts of slopes



Scenario 3

Things to consider:

- Know how using this number
- Use correct type of surface for data want to know
  - Operational use/metrics
  - Big picture planning
  - Intermediate slopes are important
- Ultimately impacts next step in calculations
  - Variable can be skewed up or down based on assumptions.

Fill Rates and Remaining Life

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Remaining Airspace	527,000 cy	527,000 cy	527,000 cy	527,000 cy
Annual Tonnage	33,000 tons	33,000 tons	***40,000 tons***	***40,000 tons***
Density *	920 lb/cy	***1,080 lb/cy***	920 lb/cy	***1,080 lb/cy***
Fill Rate	72,000 cy/yr	61,000 cy/yr	87,000 cy/yr	74,000 cy/yr
Remaining Life	**7.3 years**	**8.7 years**	**6.0 years**	**7.1 years**

**Density includes waste and soil*

What does this tell you?

Things to consider:

- Can vary:
  - Fill rate (cy/mo)
  - Waste acceptance (ton/yr) and density (lb/cy)
  - Less varying inputs, the better
- Cannot account for all variables
- Calculations are subjective
- Sensitive to assumptions
  - More critical closer to cell completion

Survey Impacts

	Scenario 1	Scenario 2	Scenario 3
Surface 1	2018 Survey	2018 Survey	2018 Survey
Boundary	Constructed Footprint	Constructed footprint	Constructed footprint
Area	22.6 acres	22.6 acres	22.6 acres
Tolerance	0'	+0.5' (high)	-.25' (low)
Tolerance Volume	**0 cy**	**+18,230 cy**	**-9,115 cy**

What does this tell you?

Things to consider:

- Survey is valid
- Survey type and equipment
- Tolerances can add up over larger areas
- These impact the numbers
- Often not discussed

- Other similar types of limitations.

Conclusions

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Volume Calculations are:

- Useful tool for numerous applications
  - Looking forward
  - Checking the past
  - Know how to use them
- Limited by
  - Inputs and outputs provided
  - Considerations of software
  - Feasibility of data collection
- Not able to predict the future
  - But can help see where came from and where going
- Subject to interpretations

Important to Know

- Volumes can change
- Volume changes impact density
- Consistency in assumptions is valuable
- Remaining life sensitive to change
  - (depending on the methodology)
- Ask questions and understand end use

Questions?

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