Time Value of Money and Optimization Process

Cost Definitions

- Inflation – increase in cost of products over time, decrease of purchasing power
- Recurring cost – a cost that happens multiple times at regular intervals (ie - rent, car loan repayment, tuition and fees, maintenance)
- Capital cost – one time cost (ie – construction, permit, machinery purchase)
- Present worth – equivalent present value of future or recurring costs

Inflation

Money loses purchasing power over time

- Average price of milk in 1995 = $2.48
- Average price of milk in 2016 = $3.17
- Average annual increase = 1%

- Average price of unleaded gasoline in 1976 = $0.61
- Average price of unleaded gasoline in 2016 = $2.10
- Average annual increase = 1.7%

Usually estimate average annual inflation = 3%

Capital Expense

- Initial, one-time cost
- Design, excavation, piping, rainwater harvest tank, construction…
- Assumes that components will last a certain period of time
- Already in present worth

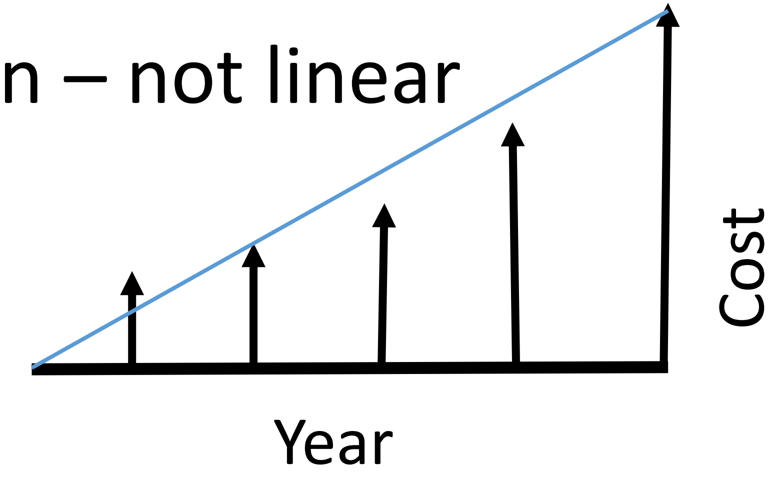
Recurring Expense

- A cost that happens multiple times at regular intervals
- Maintenance – cleaning pervious pavement, weeding, landscaping, replacing mulch layer of a rain garden, sediment and debri removal
- Inflation means maintenance will get more expensive each year

Present Worth

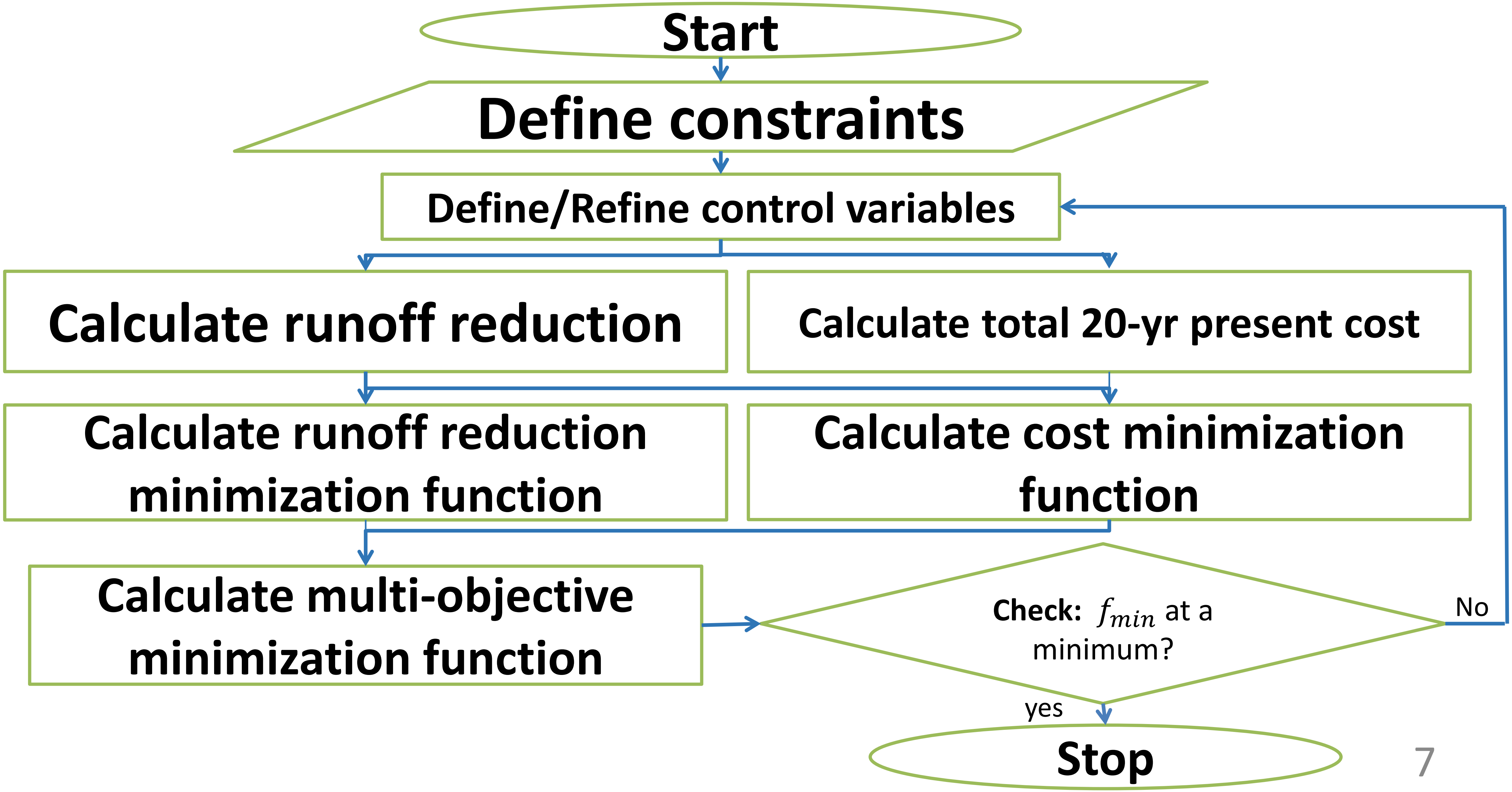
- Inflation → maintenance cost increases each year
- Geometric gradient increase, 3% inflation – not linear

$$P = A_1\left(\frac{N}{1+i}\right)$$



- P = Present value
- A_1 = First annual payment
- N = Number of years
- i = Interest rate or inflation rate

Optimization Routine



Design Constraints

<u>Fixed constraints</u>

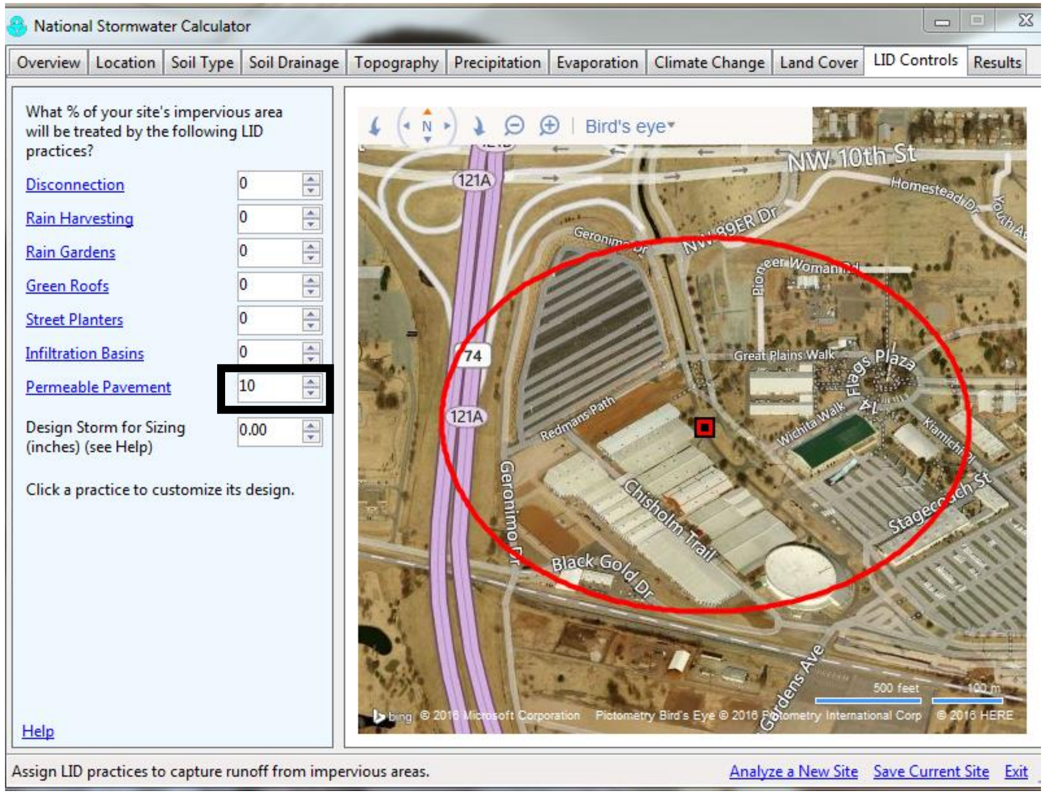
- LID can be implemented only in available space
  - Bioretention and disconnection – limited by pervious area
  - Greenroofs and rainwater harvesting – only on roof area
  - Pervious concrete and pavers – only on streets, parking lots, and sidewalk areas
  - Pervious asphalt – only on streets and parking lots

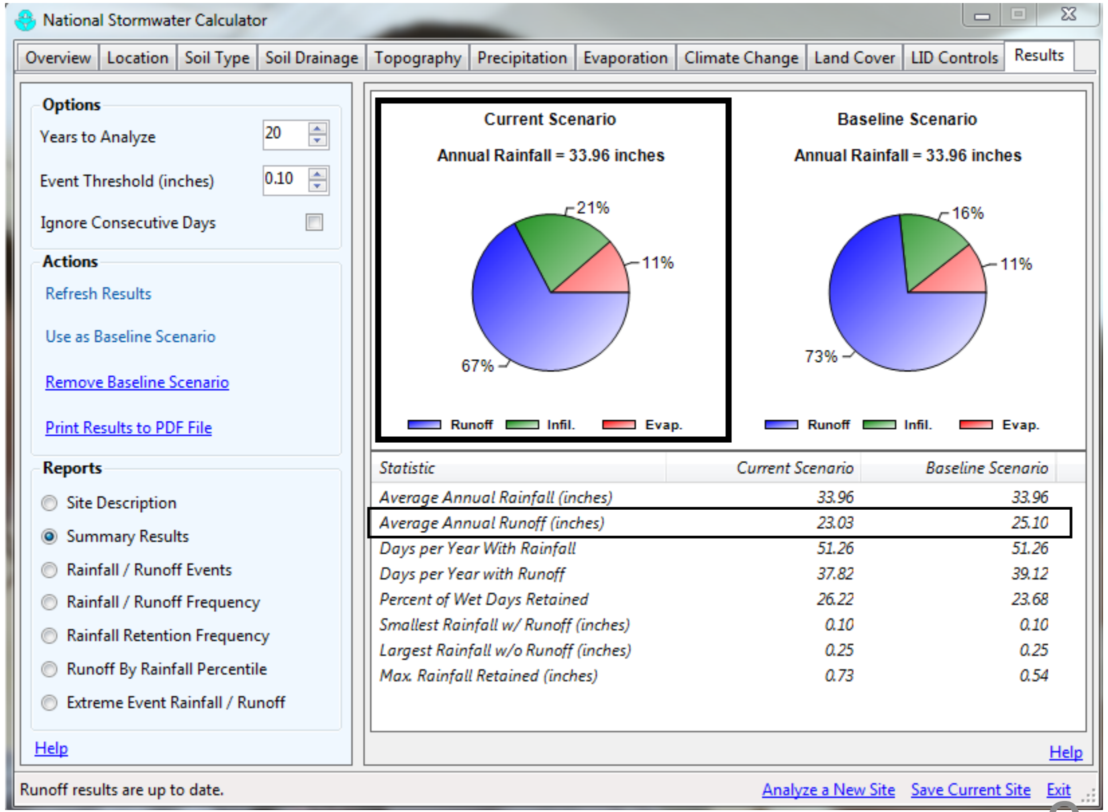
<u>Flexible constraints</u>

- Implement a certain amount of LID for other purposes – aesthetics, education, ecosystem services

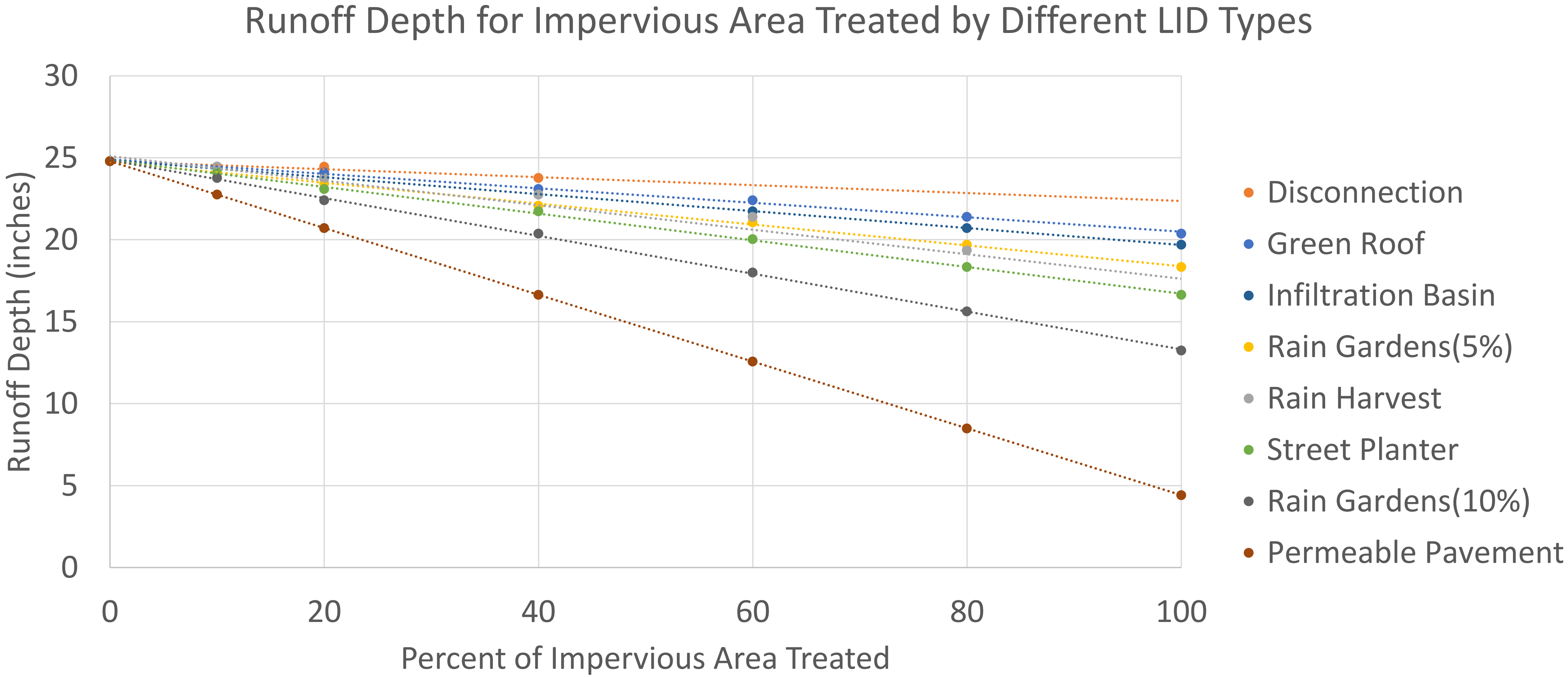
Regression

- EPA Stormwater Calculator output for different percentages of impervious area treated by each singular LID type





Regression (cont.)



Regression (cont.)

LID Type	Regression Equation
Disconnection	$D_{runoff} = -0.035(A) + 25.1$
Green Roof	$D_{runoff} = -0.047(A) + 25.1$
Rain Gardens (drainage area = 5% of treatment area)	$D_{runoff} = -0.069(A) + 25.1$
Rain Harvest	$D_{runoff} = -0.075(A) + 25.1$
Street Planter	$D_{runoff} = -0.085(A) + 25.1$
Rain Gardens (drainage area = 10% of treatment area)	$D_{runoff} = -0.12(A) + 25.1$
Permeable Pavement	$D_{runoff} = -0.21(A) + 25.1$

D_{runoff} = Depth of runoff generated
A = % Impervious area treated

Runoff Calculation

- Calculate runoff with selected amount of impervious area treated

<u>Example</u>

Treat 10% of impervious area with permeable asphalt

$$D_{runoff} = -0.21(10) + 25.1$$

D_{runoff} = 22.8 inches

$D_{reduced}$ = $D_{current} - D_{runoff}$

2.1 inches = 25.1 inches – 23 inches

(8% reduction)

Cost Calculation

- Calculate cost with selected amount of impervious area treated

<u>Example</u>

Treat 10% of impervious area with permeable asphalt

$$Present\ Cost(\$/_{ft^2}) = Capital\ Cost(\$/_{ft^2}) + Maintenance\ Cost(\$/_{ft^2}) * \left(\frac{N}{1+i}\right)$$

$$5.47(\$/_{ft^2}) = 1.5(\$/_{ft^2}) + 0.19(\$/_{ft^2}) * \left(\frac{20years}{1.03}\right)$$

10% of impervious area = 8.3 acres

$$Total\ Present\ Value\ Cost(\$) = 5.47\left(\$/_{ft^2}\right) * 8.3acres * \frac{43{,}560ft^2}{1\ acre}$$

Total Present Value Cost = $3.3 million

Minimization Functions

Calculate runoff reduction minimization function:
LID runoff depth to predevelopment runoff depth

$$Runoff\ ratio = \frac{Runoff_{LID}}{Runoff_{Pre}}$$

Calculate cost minimization function:
20-yr cost per gallon

$$\$\ per\ gallon = \frac{(20yr\ \$)}{Vol_{reduction}}$$

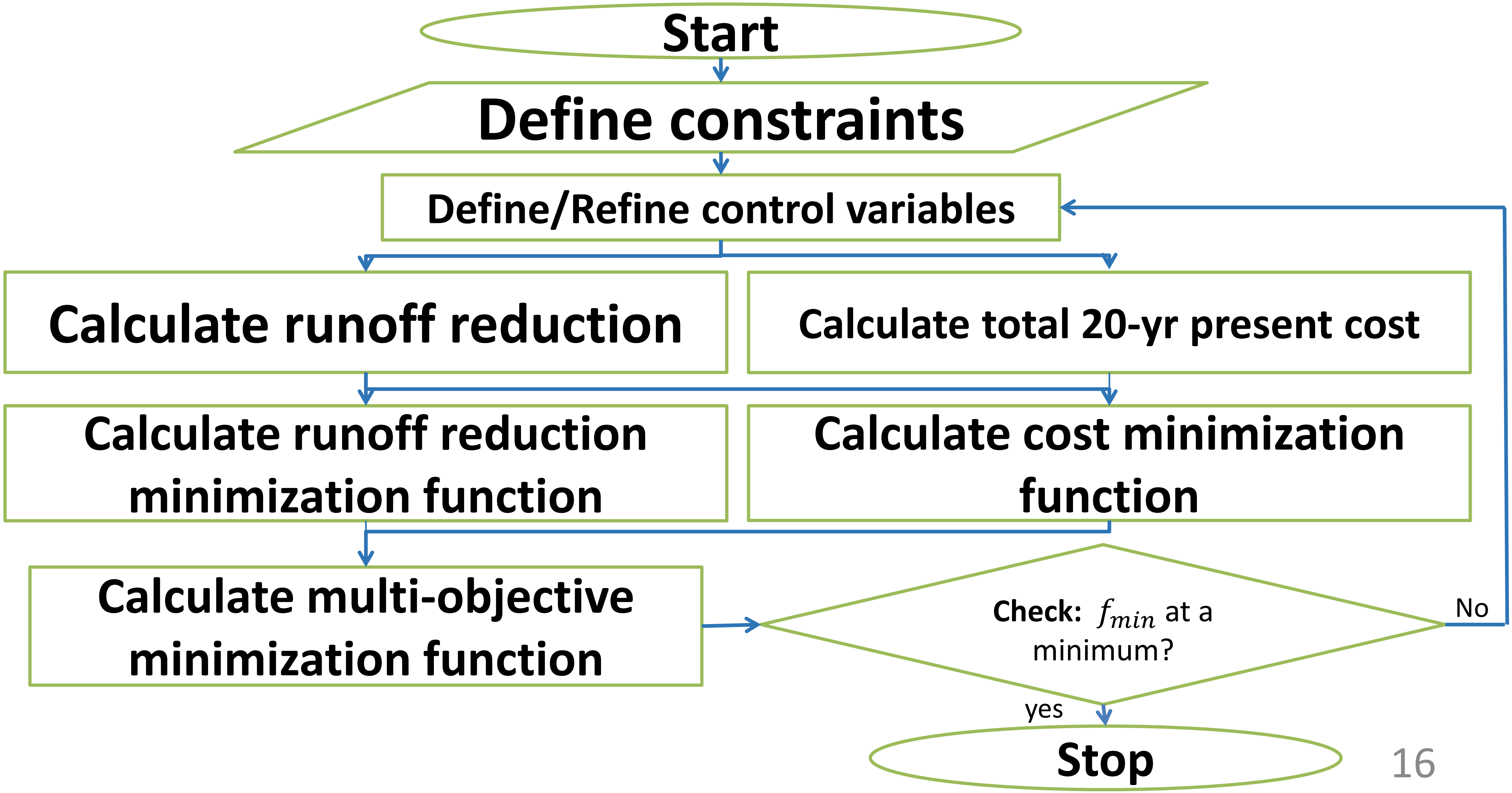
Calculate multi-objective minimization function:
Runoff reduction and cost per gallon

$$f_{min} = (Runoff\ ratio) \times (\$\ per\ gallon)$$

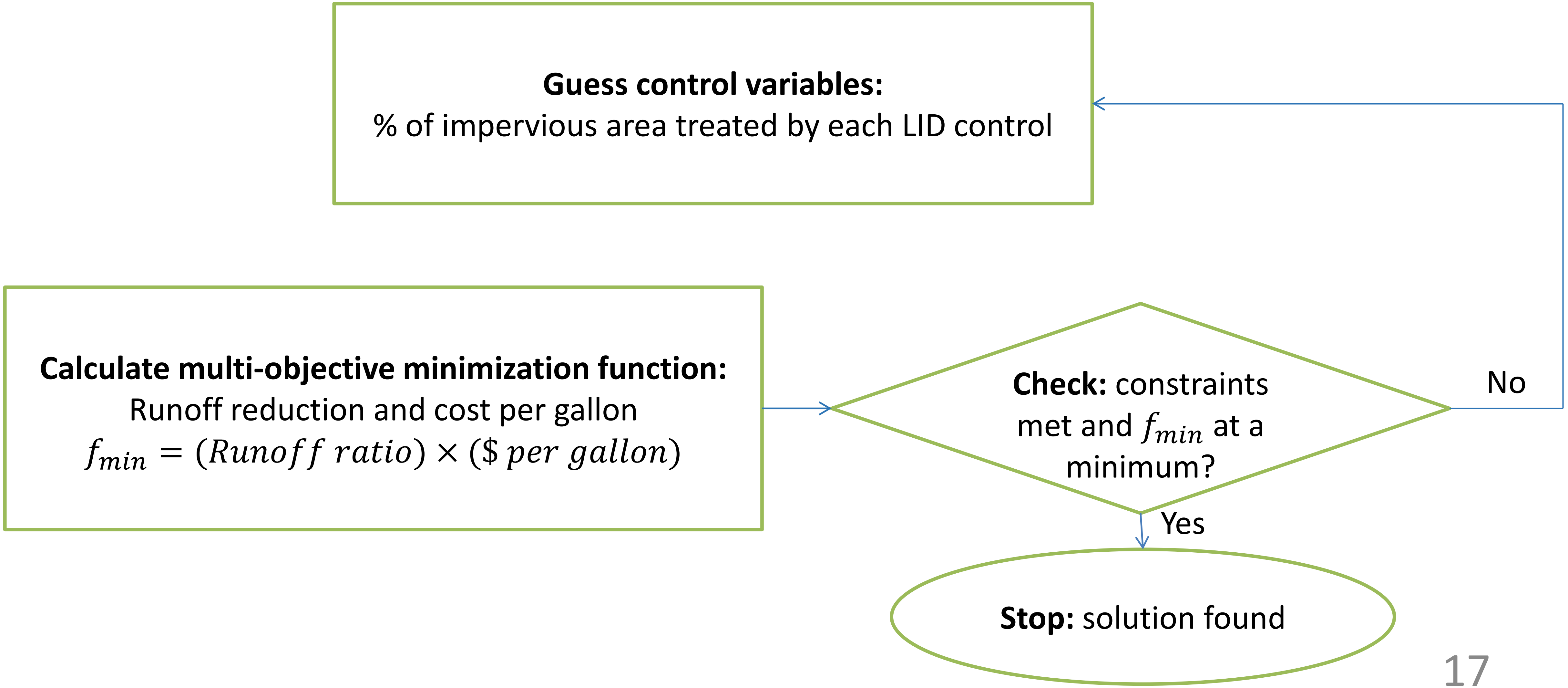
Minimization Functions

- $Runoff\ ratio = \frac{Runoff_{LID}}{Runoff_{Pre}} = \frac{23\ inches}{11.7\ inches} = 1.97$
- $\$\ per\ gallon = \frac{(20yr\ \$)}{Vol_{reduction}} = \$0.49$
- $f_{min} = (Runoff\ ratio) \times (\$\ per\ gallon) = 0.958$

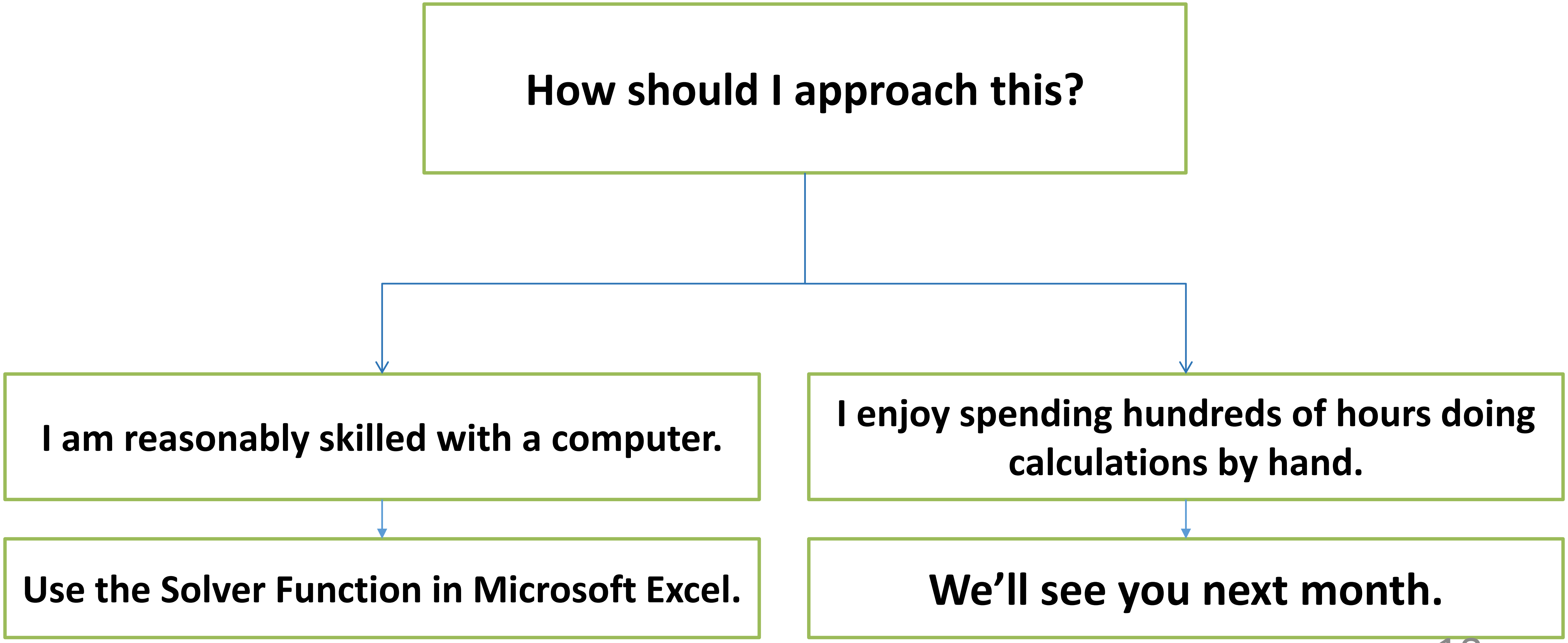
Back to the flow chart



Are we done?

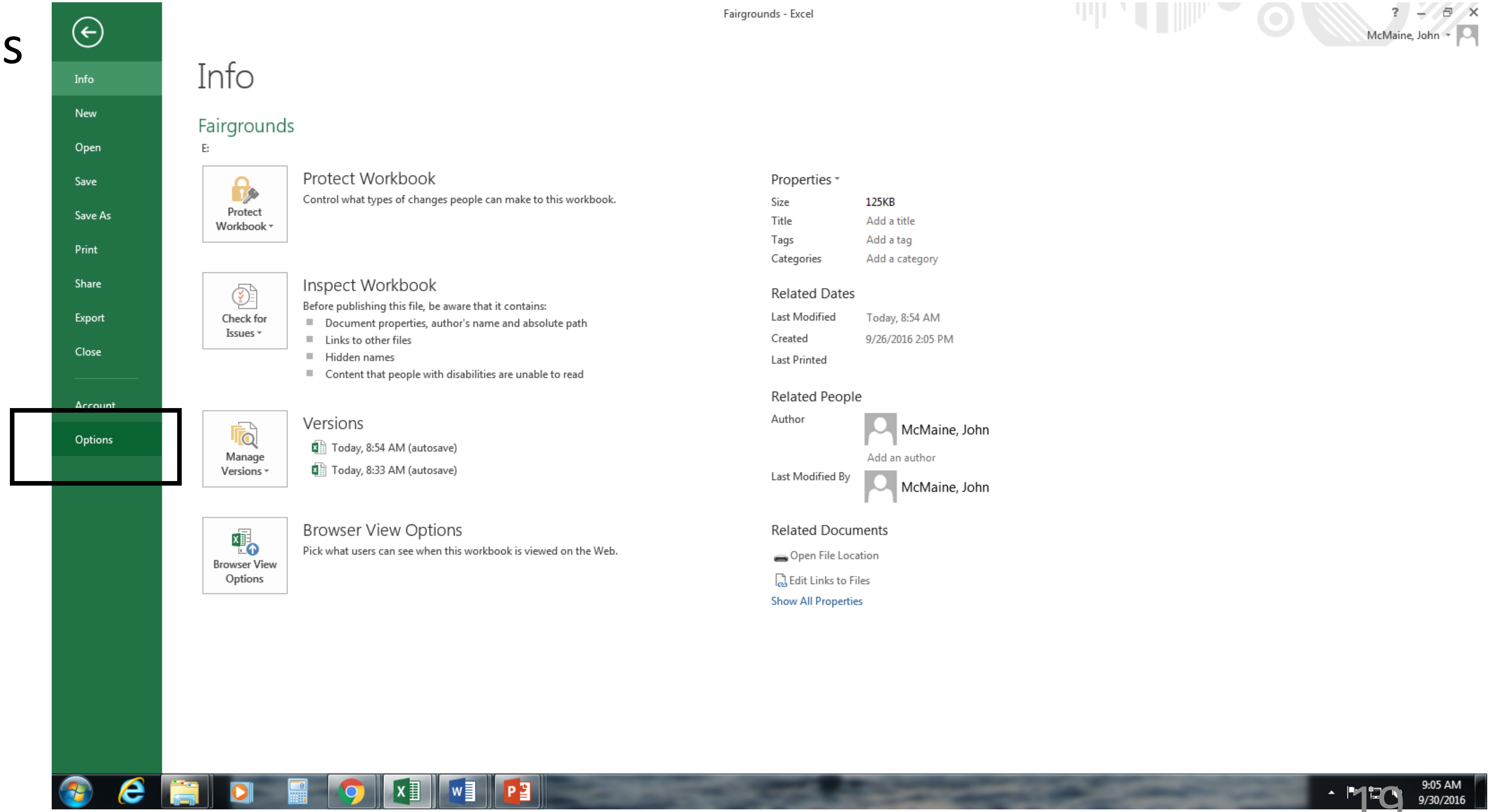

Guess control variables:
% of impervious area treated by each LID control
Calculate multi-objective minimization function:
Runoff reduction and cost per gallon
$f_{min} = (Runoff\ ratio) \times (\$\ per\ gallon)$
Check: constraints met and f_{min} at a minimum?
No
Yes
Stop: solution found

Minimization Function



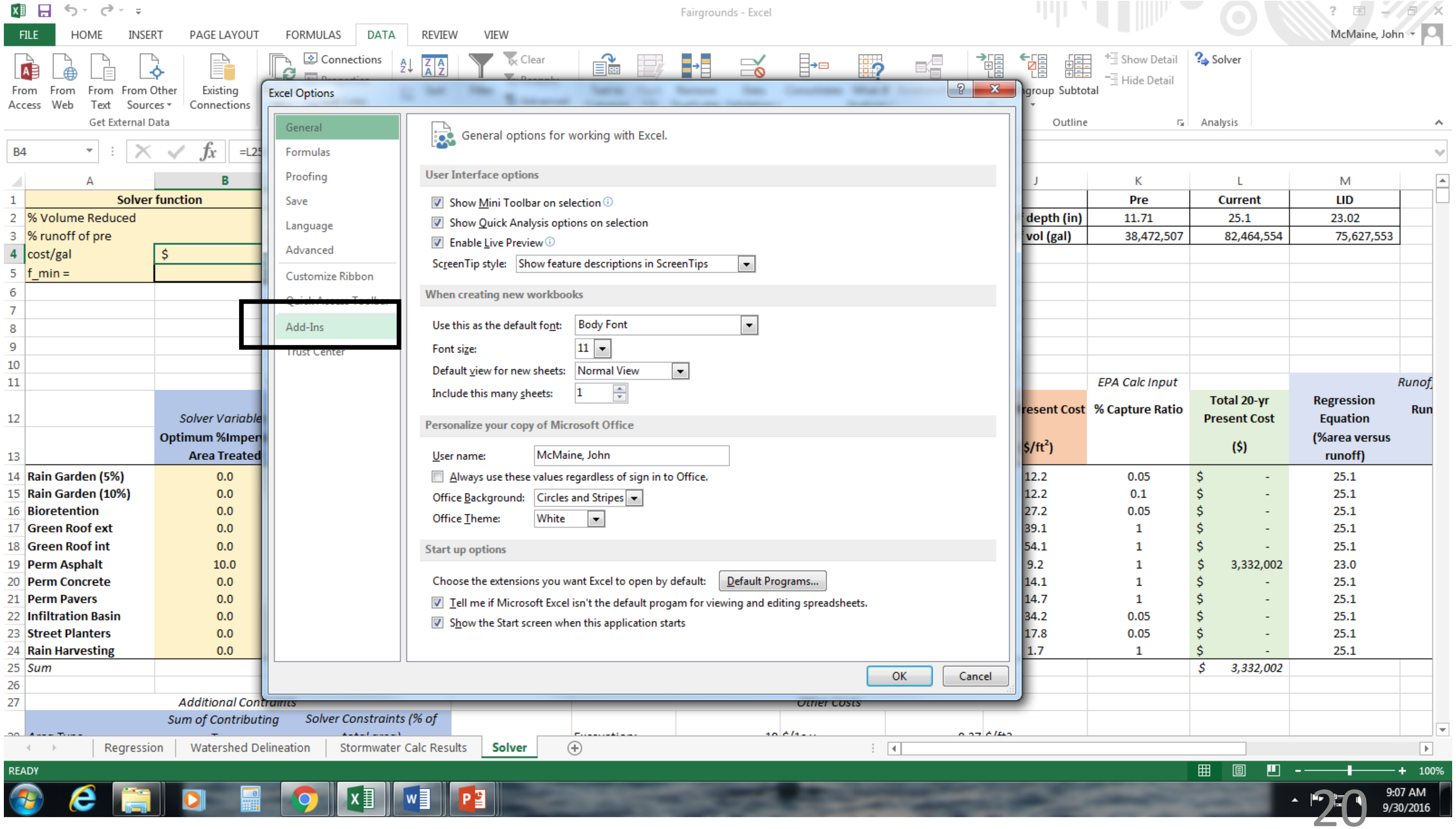
Microsoft Excel Solver

File → Options



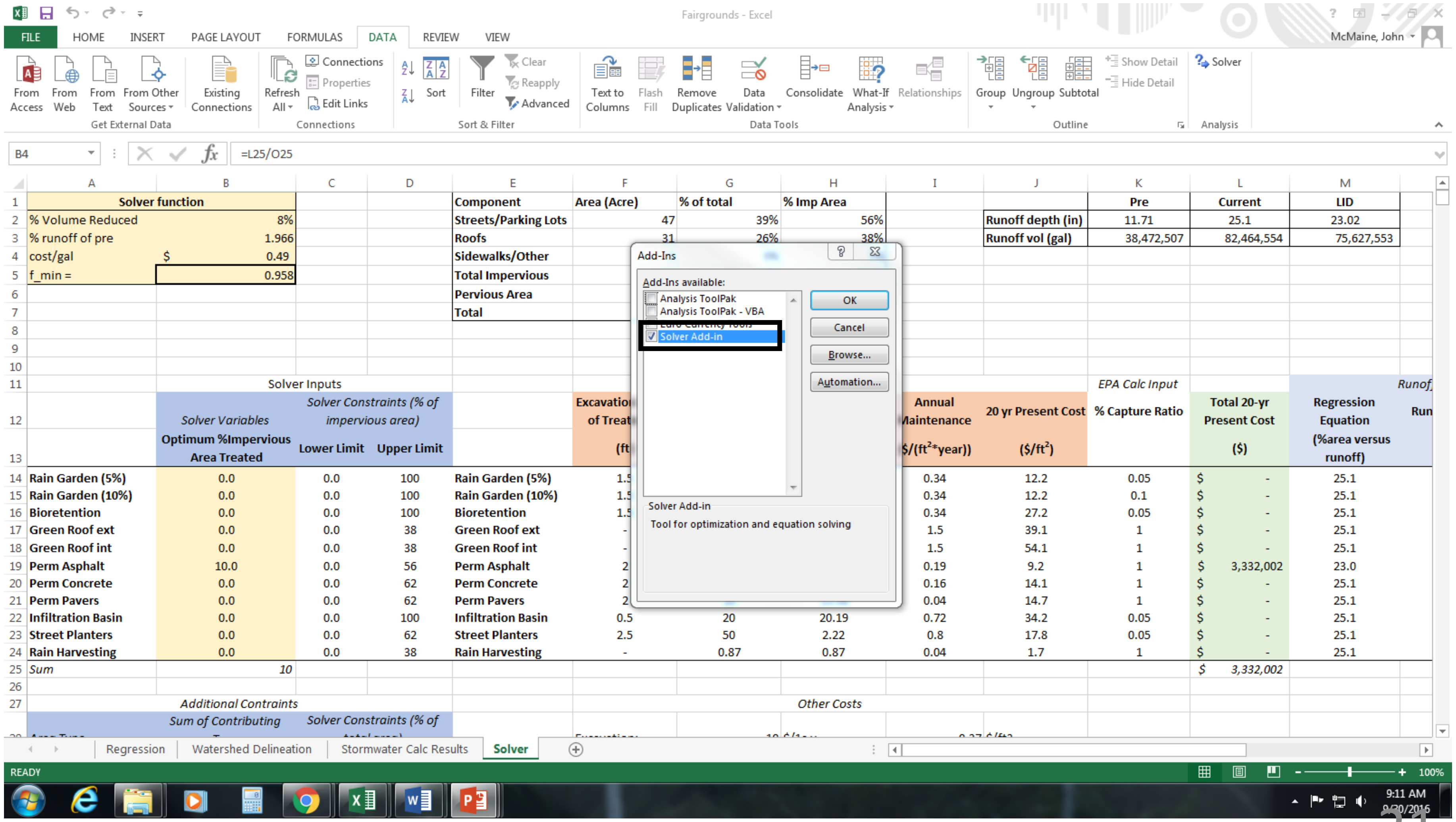
Microsoft Excel Solver

Add-Ins



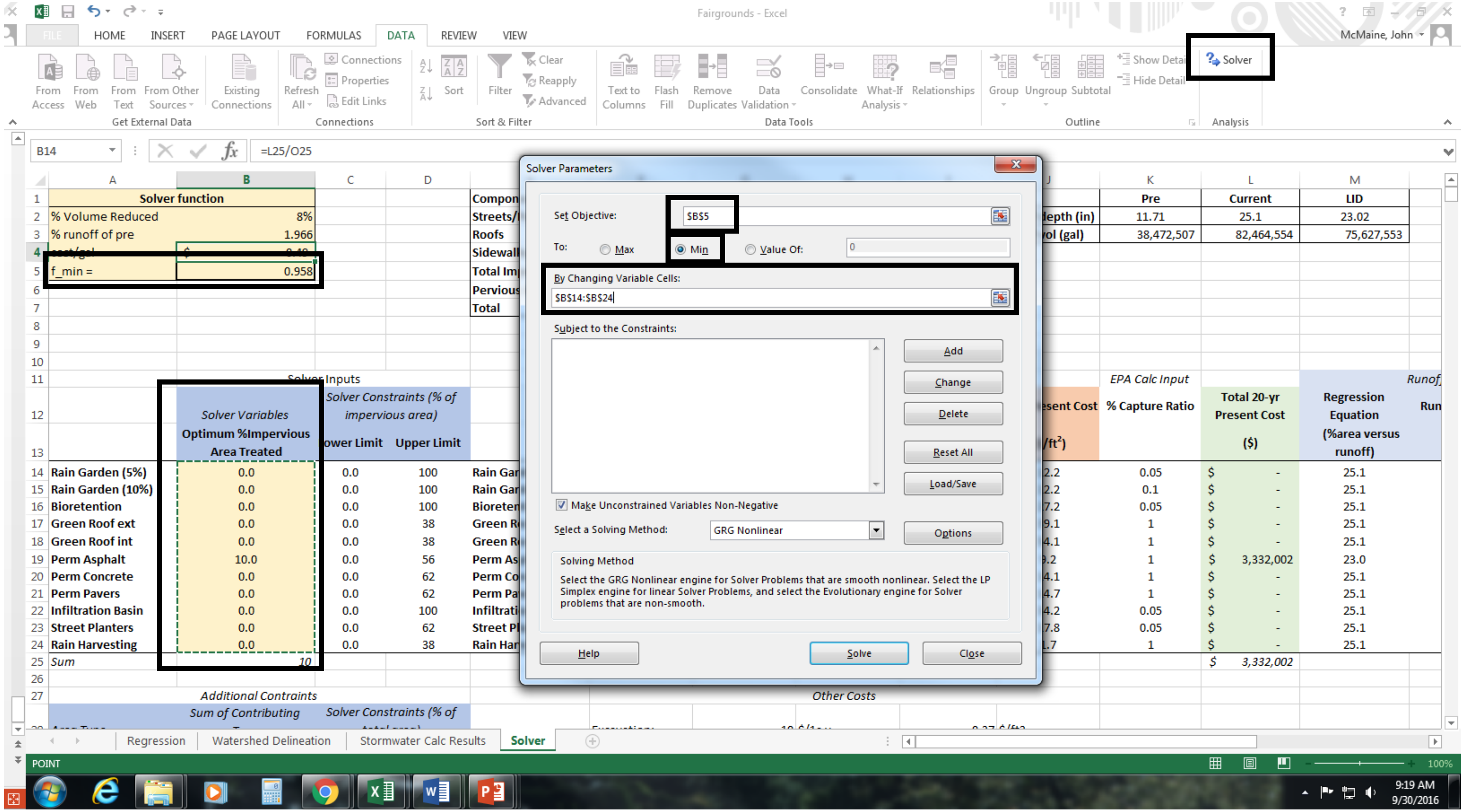
Microsoft Excel Solver

Solver Add-in



Microsoft Excel Solver

- Set Objective
- By Changing Variable Cells

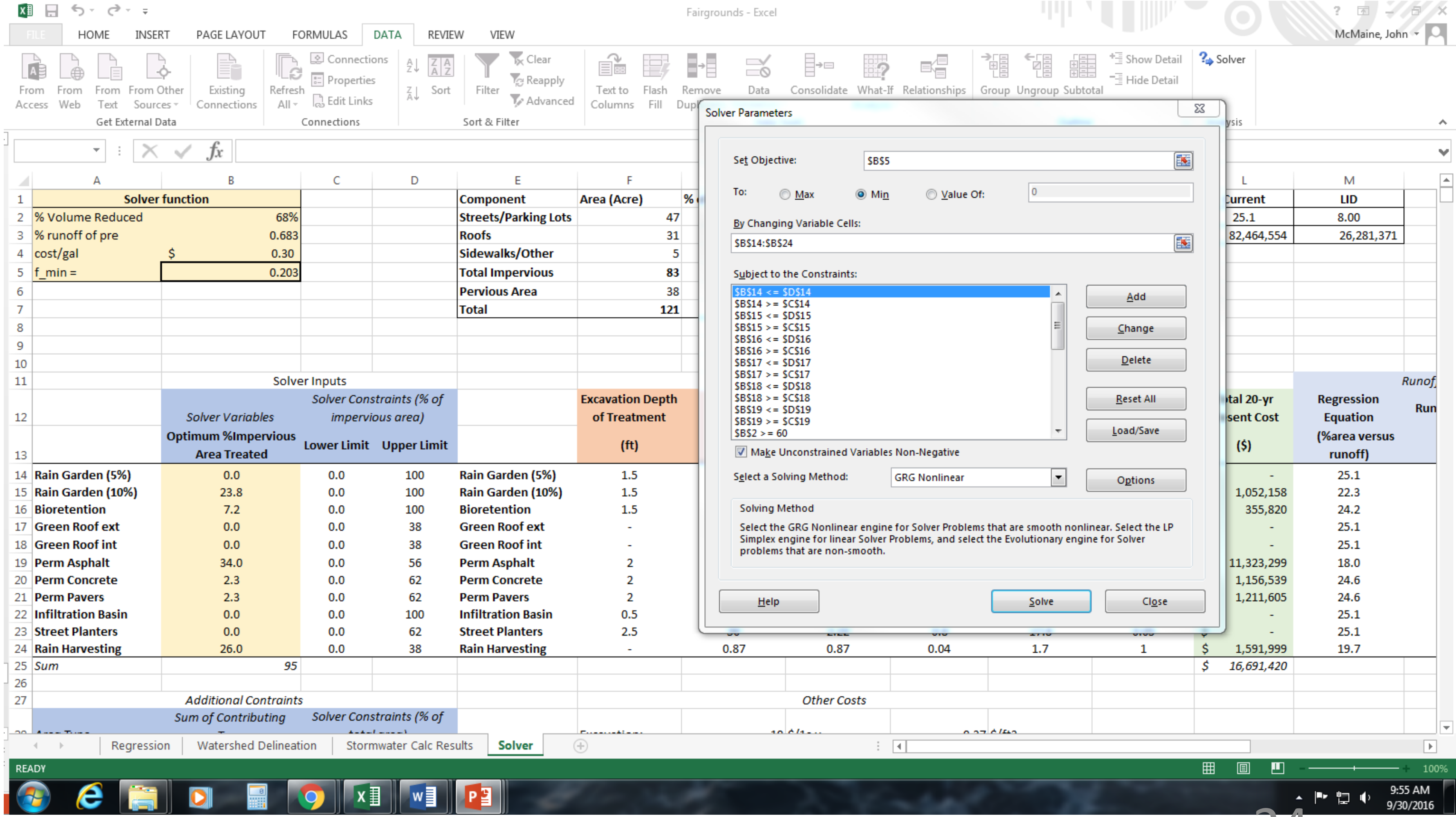


Setting Constraints

- What can be treated by each LID type?
  - Green roof and rain harvesting can only treat roof
  - Permeable asphalt can only treat streets/parking lots
  - Permeable concrete, permeable pavers, and street planters can treat streets/parking lots and sidewalks/other
  - Raingardens, bioretention, and infiltration basins can treat anything
- How much space is available for each LID type?
  - Rain gardens, bioretention, and infiltration basins compete for green space
  - Permeable asphalt, permeable concrete, permeable pavers, and street planters compete for pavement area
  - Green roofs and rain harvesting compete for roof area

Setting Constraints

- “Subject to the Constraints”
- Add



Optional Constraints

- Aesthetic or educational – want at least one green roof or rain garden
- Cost per gallon – want cost per gallon below $0.50/gallon
- Want LID runoff to equal predevelopment runoff -

$$\frac{Runoff_{LID}}{Runoff_{Pre}} = \frac{11.7\ inches}{11.7\ inches} = 1$$

- Want to reduce runoff volume by > 60%

$$\frac{Runoff_{LID}}{Runoff_{Current}} = \frac{10\ inches}{25.1\ inches} = 0.6$$

Future Optimizations

- Additional optimizations – water quality, peak flow reduction, ecosystem services
- Weighted combinations - set water quality more important than cost…
- Range of parameters set by user