Strategies on Designing Mitigation Recommendations

You want to mitigate runoff for the lowest costs. On strategy is to look at the relative costs of potential mitigation techniques, and apply the least expensive first. This will be an iterative process in which you modify layers to represent mitigation measure, e.g., adding forest canopy, then check the effectiveness after modifying layers, running your entire analysis workflow after modification. This is cumbersome, so you want to limit the number of times you go through this modify/rerun cycle.

We've listed a set of available mitigation techniques in the project description, and the cost per unit area or per water volume. You should convert all of these to costs per unit volume of water, and apply the least expensive one first, e.g.,

There is cost of $0.4 per square meter of new forest canopy, and it will reduce at most 0.85 cm of rainfall for a storm. This is 0.0085m of rainfall per square meter, or 0.0085 cubic meters of rainfall. So the per cubic meter cost is 0.4/0.0085 m^3, or
$47.06 per m^3 of water mitigation for conifer canopy.

There are limitations to how much canopy you can add. You have to plant trees existing soil, and you can't add canopy over existing canopy. Conifers intercept more, but do not have as broad a canopy so won't cover as much of a road when planted streetside. One strategy is to plant conifers most places, and deciduous trees near wider roads.

Surface sinks (rain gardens) cost $90/square meter, but can only be 0.5 meters deep, so $90/0.5 m^3, or
$180 per m^3 of water storage.

There are also restrictions on the size, location, and placement of raingardens and other surface sinks; they can only go on areas currently in grass, dirt, or low canopy, and must be within 5 meters of an existing flowpath. They also cannot absorb more than the amount of water calculated for their flowpath connection. This means the maximum area in square meters for a rain garden is two times the flow accumulation in cubic meters on the flowpath at that point.

Converting parking lots, roads, and other hard surfaces to permeable pavement is also an option, but remember that it is limited by the infiltration amount of the underlying soil. It is less expensive per unit water volume on more porous soils than less porous soils, but there is still a limit.

Excessively drained soils can absorb the first 0.056 m of rain (or 0.056 m^3), and it costs $150 m^3 to convert concrete to pervious concrete or road, so the cost per m^3 is $150/0.050 = $3,000 per m^3. We use 0.05 instead of 0.056 because we're only interested in collections up to the first 5 cm storm

Costs for other soil types are:
$8,000 per m^3 for well-drained soils ($150/(0.025*0.075)), and
$16,000 per m^3 for urban soils ($150/(0.0125*0.075)).

Green roofs cost $500 per square meter, but only can absorb the first 0.05 m of rain, for a cost per cubic meter of 500/0.05 = $10,000.

The underground storage cost per m^3 is $26,000 (not the $2,600 cost listed in the initial posting of the project description).

From the costs, it is obvious you should start by adding as much canopy as possible. Perhaps the best way to do this is via digitizing a point layer, representing the planting locations of new, tall, trees. You then buffer around these new trees using the limits described in the project, 7.5 meter radius for conifers, 13 meter radius for deciduous trees. You don't have to be too careful about the spacing of the points, because the cost is per unit crown area, which the buffers will create, removing overlap.

You should buffer two new layers, one of added conifer, and another of added deciduous crowns. You then need to clip these layers by the existing canopy (new canopy can't grow into old canopy, just next to). You can then calculate the area of new canopy, for cost.

You then must add this new canopy to the old canopy layer, most easily by unioning the clipped canopy with the existing canopy.

You can now re-run your runoff analysis, and see how many cubic meters of water still remain.

Surface sinks are the next least costly alternative, so you should place these after you've exhausted opportunities for added canopy. Grassy areas or parking lots near flowlines are best, particularly lower down in the watershed, nearer the outlet. Remember that some part of the new rain garden has to be within 5 meters of the flowline, you can use the measure tool or visually place it, you don't need to buffer flowlines. You can gain a rough estimate of the amount of water draining to the point by "eyeballing" upstream area, and estimating the area of added canopy, then multiplying by the approximate average interception for this new canopy. This might give a general target for rain garden area. Since the maximum depth of a rain garden is 0.5 meters, multiplying volume target by 2 will give you the area needed for the rain garden. For example, if I have 6 m^3 of water to collect in a rain garden, I need to make it 6 x 2 or 12 m^2 in surface area to hold the 6 m^3.

Note that you can use this rough estimate method for sizing your digitized rain garden, but you need to calculate the actual amount by placing a new pourpoint, then re-running the snap pourpoints/watershed/zonal sum or union/statistics commands to calculate the new embedded watershed and runoff volume. You can then count a "credit" for the amount

You build rain gardens within a watershed until you've run out of space, or you've reached the total amount of runoff you have to mitigate. You need to be a bit careful if you place a rain garden in a branch that has rain garden downstream. You can't capture the same water twice. You can either track this manually, discounting downstream measured flow for the amount captured upstream, or by putting new pour points by each rain garden and calculating new "subwatersheds," within the five target watersheds. It may seem that the manual method is quicker, but in the long run, creating subwatersheds is usually less work in repeat analysis.

Once you've exhausted the rain garden possibilities, you need to select your next method for mitigation. For some watersheds, conversion of some of the area to permeable pavement/concrete will be the next least costly mitigation. For others, it will be green roofs. You should look at the soil types that dominate the watershed, and costs.

Substituting pervious pavement consists of making a copy of the existing impervious surface layer, and converting some to pervious surface. You'll need to measure the area converted to estimate cost. You can get a rough estimate of the amount you need to convert by first calculating the amount of water you save for each square meter converted, then divide that into the amount of runoff still extant in your watershed. This will give a target area. This will be approximate; you will need to re-run you analysis with your new permeabilities (and new canopy and rain gardens), to give yourself an exact estimate of runoff.

Once permeable surface conversion and green roofs opportunities are exhausted, the only thing you can do is add underground storage. This consists of just digitizing a point for each branch where you need underground storage, usually near the outlet, and calculating a volume and cost there.

As you might guess, this is an iterative process, so you will have to run your runoff model several times. In as much as you have parts of it automated with something like model builder, you will have an easier time. Even if you do automate portions of the analysis, but especially if you don’t, you will have to be very organized in your runs. I’d suggest you create a copy of the project for each major step, e.g., one for canopies, then when that is done, copy that, and modify for a project with canopies and rain gardens, then when that is done, a project for canopies, rain gardens, and pervious surfaces. Within each of these you may have several runs, so your files will multiply. If you don’t start fresh with just the minimum needed files at each step, your geodatabase my get cluttered to the point of confusion.