**Analysing a Network**

*After a network has been suitably described, its hydraulic and water quality behaviour can be analysed. This chapter describes how to specify options to use in the analysis, how to run the analysis and how to troubleshoot problems that might have occurred with the analysis.*

## **Setting Analysis Options:**

There are five categories of options that control how EPANET analyses a network: Hydraulics, Quality, Reactions, Times, and Energy. To set any of these options:

1. Select the Options category from the Data Browser or select **Project >> Analysis Options** from the menu bar.
2. Select Hydraulics, Quality, Reactions, Times, Energy from the Browser.
3. Edit your option choices in the Property Editor.

**Hydraulic Options:**

Hydraulic options control how the hydraulic computations are carried out.

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| **OPTION** | **DESCRIPTION** |
| Flow Units | Units in which nodal demands and link flow rates are expressed. |
| Headloss Formula | Formula used to compute Headloss as a function of flow rate in a pipe. Hazen-Williams, Darcy-Weisbach, Chezy-Manning. Because each formula measures pipe roughness differently, switching formulas might require that all pipe roughness coefficients be updated. |
| Specific Gravity | Ratio of the density of the fluid being modelled to that of water at 4C |
| Relative Viscosity | Ratio of the kinematic viscosity of the fluid to that of water at 20C |
| Maximum Trials | Maximum number of trials used to solve the nonlinear equations that govern network hydraulics at a given point in time. Suggested value is 40. |
| Accuracy | Convergence criterion used to signal that a solution has been found to the nonlinear equations that govern network hydraulics. Trials end when the sum of all flow changes divided by the sum of all link flows is less than this number. Suggested value is 0.001. |
| If Unbalanced | Action to take if a hydraulic solution is not found within the maximum number of trials. Choices are STOP to stop the simulation at this point or CONTINUE to use another 10 trials, with no link status changes allowed, in an attempt to achieve convergence. |
| Default Pattern | ID label of a time pattern to be applied to demands at those junctions where no time pattern is specified. If no such pattern exists then demands will not vary at these locations. |
| Demand Multiplier | Global multiplier applied to all demands to make total system consumption vary up or down by a fixed amount |
| Emitter Exponent | Power to which pressure is raised when computing the flow through an emitter device. The textbook value for nozzles and sprinklers is 0.5. This may not apply to pipe leakage. |
| Status Report | Amount of status information to report after an analysis is made. Choices are: NONE (no reporting), YES (link status changes), FULL (normal plus convergence). Full status reporting is only useful for debugging purposes. |
| Max. Head Error | Augments the ACCURACY option. Specifies the maximum head loss error any network link can have for hydraulic convergence to occur. The default value of 0 indicates that no head error limit applies. |
| Max. Flow Change | Augments the ACCURACY option. Specifies the largest change in flow that any network element can have for hydraulic convergence to occur. The default value of 0 indicates that no flow change limit applies. It is specified based on the current project flow unit setting. |
| Demand Model | Selects between demand or pressure driven analysis – DDA or PDA, respectively. DDA assumes demands are fixed at a given point in time, while PDA assumes demands are a function of pressure. The PDA option can be used to find a solution when negative pressures are present in a DDA. |
| Minimum Pressure | In a PDA, the pressure below which demand is assumed to be zero. |
| Required Pressure | In a PDA, the pressure required to deliver the full demand. |
| Pressure Exponent | PDA assumes a pressure demand relation raised to an exponent. Standard value is 0.5. |
| CHECKFREQ | This sets the number of solution trials that pass during hydraulic balancing before the status of pumps, check valves, flow control valves and pipes connected to tanks are once again updated. The default value is 2, meaning that status checks are made every other trial. The frequency of status checks on pressure reducing and pressure sustaining valves (PRVs and PSVs) is determined by the DAMPLIMIT option. |
| MAXCHECK | This is the number of solution trials after which periodic status checks on pumps, check valves, flow control valves and pipes connected to tanks are discontinued. The default value is 10, meaning that after 10 trials, instead of checking status every CHECKFREQ trials, status is checked only at convergence. |
| DAMPLIMIT | This is the accuracy value at which solution damping and status checks on PRVs and PSVs should begin. The default is 0 which indicates that no damping should be used and that status checks on control valves are made at every iteration. Damping might be needed on networks that have trouble converging, in which case a limit of 0.01 is suggested. |

Below are some typical values that might be used for the status checking parameters:

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| **CHECKFREQ** | **MAXCHECK** | **DAMPLIMIT** | **REMARKS** |
| 2 | 10 | 0 | Frequent status checking; tends to produce solutions in the least number of iterations. |
| 10 | 100 | 0.01 | Less frequent status checking; might be needed for networks that have difficult in converging. |
| Max. Trials | Max. Trials | Convergence Accuracy | Status checks made only after convergence is achieved; might produce convergence when other settings fail. |

**Water Quality Options:**

Water Quality Options control how the water quality analysis is carried out.

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| **OPTION** | **DESCRIPTION** |
| Parameter | Type of water quality parameter being modelled. Choices include: None, Chemical (compute concentration), Age (estimate water age), Trace (percent flow from node). In lieu of Chemical, you can enter the actual name of the chemical being modelled |
| Mass Units | Mass units used to express concentration. Choices are mg/L ug/L. Units for Age and Trace analyses are fixed at hours and percent. |
| Relative Diffusivity | Ratio of the molecular diffusivity of the chemical being modelled to that of chlorine at 20C, etc. Set to zero to ignore mass transfer effects. |
| Trace Node | D label of the node whose flow is being traced. Applies only to flow tracing analyses. |
| Quality Tolerance | Smallest change in quality that will cause a new parcel of water to be created in a pipe. A typical setting might be 0.01 for chemicals measured in mg/L as well as water age and source tracing. |

**Reaction Options:**

Reaction Options set the types of reactions that apply to a water quality analysis.

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| **OPTION** | **DESCRIPTION** |
| Bulk Reaction Order | Power to which concentration is raised when computing a bulk flow reaction rate. Use 1 for first-order reactions, 2 for second-order reactions, etc. Use any negative number for Michaelis-Menton kinetics. If no global or pipe-specific bulk reaction coefficients are assigned then this option is ignored. |
| Wall Reaction Order | Power to which concentration is raised when computing a bulk flow reaction rate. Choices are 1 for first-order reactions 0 for constant rate reactions. If no global or pipe-specific wall reaction coefficients are assigned then this option is ignored. |
| Global Bulk Coefficient | Default bulk reaction rate coefficient Kb assigned to all pipes. Use a positive number for growth, a negative number for decay, or 0 if no bulk reaction occurs. |
| Global Wall Coefficient | Wall reaction rate coefficient Kw assigned to all pipes. Use a positive number for growth, a negative number for decay, or 0 if no wall reaction occurs. |
| Limiting Concentration | Maximum concentration that a substance can grow to or minimum value it can decay to. Set to zero if not applicable. |
| Wall Coefficient Correlation | Factor correlating wall reaction coefficient to pipe roughness. Set to zero if not applicable. |

**Times Options:**

Times options set values for the various time steps used in an extended period simulation.

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| **OPTION** | **DESCRIPTION** |
| Total Duration | Total length of a simulation in hours. Use 0 to run a single period (snapshot) hydraulic analysis. |
| Hydraulic Time Step | Time interval between re-computation of system hydraulics. Normal default is 1 hour. |
| Quality Time Step | Time interval between routing of water quality constituent. Normal default is 5 minutes (0:05 hours). |
| Pattern Time Step | Time interval used with all the time patterns. Normal default is 1 hour. |
| Pattern Start Time | Hours into all the time patterns at which the simulation begins (e.g., a value of 2 means that the simulation begins with all the time patterns starting at their second hour). Normal default is 0. |
| Reporting Time Step | Time interval between times at which computed results are reported. Normal default is 1 hour. |
| Report Start Time | Hours into simulation at which computed results begin to be reported. Normal default is 0. |
| Starting Time of Day | Clock time (e.g., 7:30 am, 10:00 pm) at which simulation begins. Default is 12:00 am (midnight). |
| Statistic | Type of statistical processing used to summarize the results of an extended period simulation. Choices are: NONE (current time step results), AVERAGE (time-averaged results), MINIMUM (minimum value results), MAXIMUM (maximum value results), RANGE (diff between min and max). Statistical processing is applied to all node and link results obtained between the Report Start Time and the Total Duration. |

**Energy Options:**

Energy Analysis Options provide default values used to compute pumping energy and cost when no specific energy parameters are assigned to a given pump.

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| **OPTION** | **DESCRIPTION** |
| Pump Efficiency (%) | Default pump efficiency. |
| Energy Price per Kwh | Price of energy per kilowatt-hour. |
| Price Pattern | ID label of a time pattern used to represent variations in energy price with time. Leave blank if not applicable. |
| Demand Charge | Additional energy charge per maximum kilowatt usage. |

## **Running an Analysis:**

To run a hydraulic/water quality analysis:

1. Select **Project >> Run Analysis** or click image113 on the Standard Toolbar.
2. The progress of the analysis will be displayed in a Run Status window.
3. Click **OK** when the analysis ends.

If the analysis runs successfully the image114 icon will appear in the Run Status section of the Status Bar at the bottom of the EPANET workspace. Any error or warning messages will appear in a Status Report window. If you edit the properties of the network after a successful run has been made, the faucet icon changes to a broken faucet indicating that the current computed results no longer apply to the modified network.

## **Troubleshooting Results:**

EPANET will issue specific Error and Warning messages when problems are encountered in running a hydraulic/water quality analysis

**Pumps Cannot Deliver Flow or Head:**

EPANET will issue a warning message when a pump is asked to operate outside the range of its pump curve. If the pump is required to deliver more head than its shutoff head, EPANET will close the pump down. This might lead to portions of the network becoming disconnected from any source of water.

**Network is Disconnected:**

EPANET classifies a network as being disconnected if there is no way to provide water to all nodes that have demands. This can occur if there is no path of open links between a junction with demand and either a reservoir, a tank, or a junction with a negative demand. If the problem is caused by a closed link EPANET will still compute a hydraulic solution (probably with extremely large negative pressures) and attempt to identify the problem link in its Status Report. If no connecting link(s) exist EPANET will be unable to solve the hydraulic equations for flows and pressures and will return an Error 110 message when an analysis is made. Under an extended period, simulation, it is possible for nodes to become disconnected as links change status over time.

**Negative Pressures Exist:**

When performing a demand driven analysis (DDA), EPANET will issue a warning message when it encounters negative pressures at junctions that have positive demands. This usually indicates that there is some problem with the way the network has been designed or operated. Negative pressures can occur when portions of the network can only receive water through links that have been closed off. In such cases an additional warning message about the network being disconnected is also issued.

Alternatively, a pressure driven analysis (PDA) can be performed to determine a hydraulic solution assuming a pressure-demand relationship at junctions. The hydraulic solution found will have reduced or zero demands and negative pressures will be largely eliminated. This is considered a more “realistic” solution since large negative pressures in a network are not physically realistic.

**System Unbalanced:**

A System Unbalanced condition can occur when EPANET cannot converge to a hydraulic solution in some time period within its allowed maximum number of trials. This situation can occur when valves, pumps, or pipelines keep switching their status from one trial to the next as the search for a hydraulic solution proceeds. For example, the pressure limits that control the status of a pump may be set too close together. Or a pump’s head curve might be too flat causing it to keep shutting on and off.

To eliminate the unbalanced condition one can try to increase the allowed maximum number of trials or loosen the convergence accuracy requirement. Both of these parameters are set with the project’s Hydraulic Options. If the unbalanced condition persists, then another hydraulic option, labelled “If Unbalanced”, offers two ways to handle it. One is to terminate the entire analysis once the condition is encountered. The other is to continue seeking a hydraulic solution for another 10 trials with the status of all links frozen to their current values. If convergence is achieved then a warning message is issued about the system possibly being unstable. If convergence is not achieved then a “System Unbalanced” warning message is issued. In either case, the analysis will proceed to the next time period.

If an analysis in a given time period ends with the system unbalanced then the user should recognize that the hydraulic results produced for this time period are inaccurate. Depending on circumstances, such as errors in flows into or out of storage tanks, this might affect the accuracy of results in all future periods as well.

**Hydraulic Equations Unsolvable:**

Error 110 is issued if at some point in an analysis the set of equations that model flow and energy balance in the network cannot be solved. This can occur when some portion of a system demands water but has no links physically connecting it to any source of water. In such a case EPANET will also issue warning messages about nodes being disconnected. The equations might also be unsolvable if unrealistic numbers were used for certain network properties.