

Univerzitet u Beogradu, Građevinski fakultet



Analiza gubitaka u vodovodnoj mreži



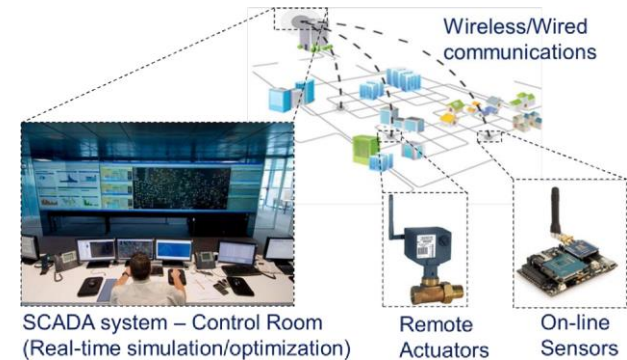
Merenja u hidrotehnici

8. Vežba

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ANALIZA GUBITAKA U VODOVODU

Šta su gubici?

Razlika između ukupne količine vode koja se upusti u distributivni sistem na postrojenju za prečišćavanje vode za piće i ukupne fakturisane količine vode!

Poreklo gubitaka u vodovodnoj mreži?



Loši spojevi cevi



Oštećenja cevi



Nelegalni priključci

Cilj: Detektovati gubitke (lokaciju i količinu) kako bi se na vreme uklonili/smanjili!

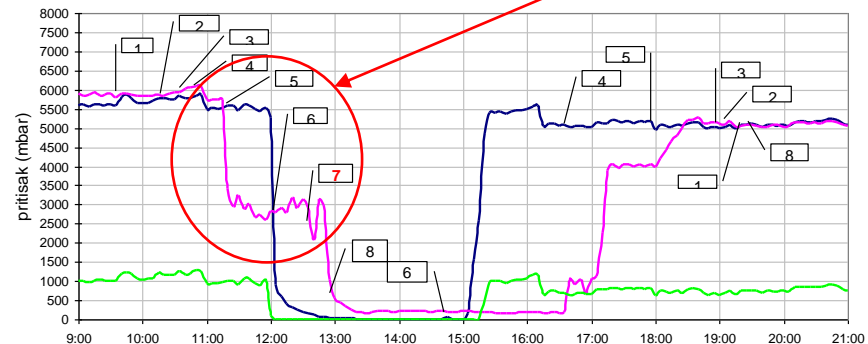
ANALIZA GUBITAKA U VODOVODU

Kako detektovati gubitke?

- Neophodna mreža senzora za praćenje pritiska (i protoka)
- Svaka nagla promena pritiska (ili protoka) može da ukaže na promenu nastalu u sistemu (npr. gubici)



Nagli pad pritiska – mogući gubici



ANALIZA GUBITAKA U VODOVODU

Kako detektovati gubitke?

- Metode osluškivanja (registrovanje promene zvuka usled curenja vode)



ANALIZA GUBITAKA U VODOVODU

Kako detektovati gubitke?

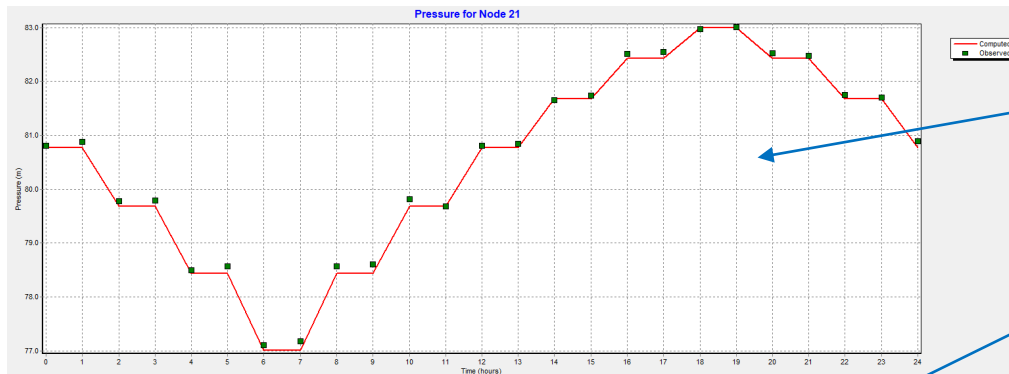
- A kad nema senzora? Kada se na ulici pojavi velika količina vode



ANALIZA GUBITAKA U VODOVODU

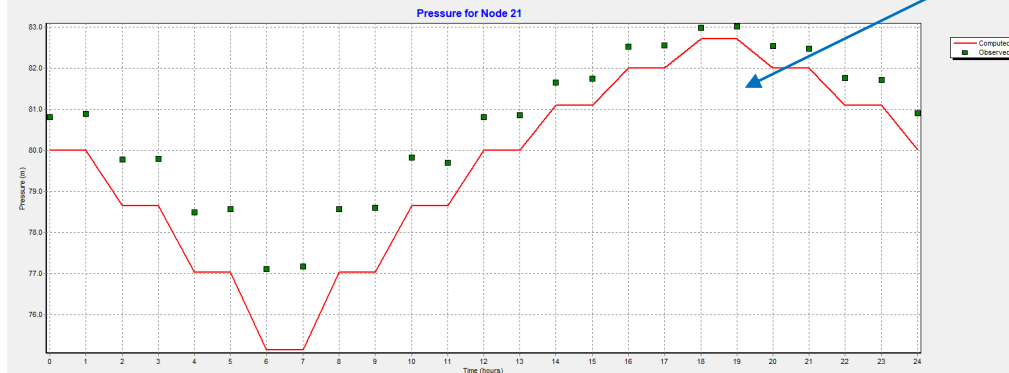
Kako detektovati gubitke?

- Kombinacija (poređenje) merenja i matematičkog modela vodovodne mreže (najčešće model kvazi-ustaljenog tečenja)



Očekivani uslovi – matematički model i merenja se u najvećoj meri poklapaju

Promenjeni uslovi – matematički model ne zna da se nešto desilo u stvarnom sistemu, otud i neslaganja



Podešavanjem ulaznih podataka za model može se ponovo doći do poklapanja rezultata. Može se reći da su na taj način detektovane promene na stvarnom sistemu.

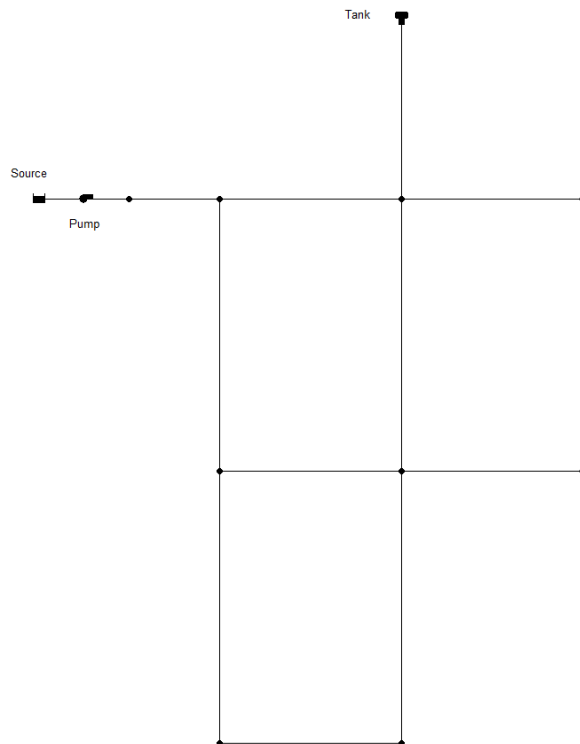
ANALIZA GUBITAKA U VODOVODU

Kako podesiti ulazne podatke tako da odgovaraju stvarnom stanju?

- **Pristup pokušaja i greške (eng. „trial & error“)**
 - **Prednosti: lako se koristi**
 - **Mane: iziskuje vreme, iskustvo i ne garantuje dobre rezultate**
- **Neki drugi (napredniji) pristup**
 - **Prednosti: u slučaju složenijih sistema iziskuje manje vremena od „trial & error“ pristupa, može dovesti do boljeg rešenja, radi automatski**
 - **Mane: zahteva znanje programiranja i metoda optimizacije**

ANALIZA GUBITAKA U VODOVODU

U ovoj vežbi se koristi „trial & error“ pristup za određivanje gubitaka u zadatoj vodovodnoj mreži



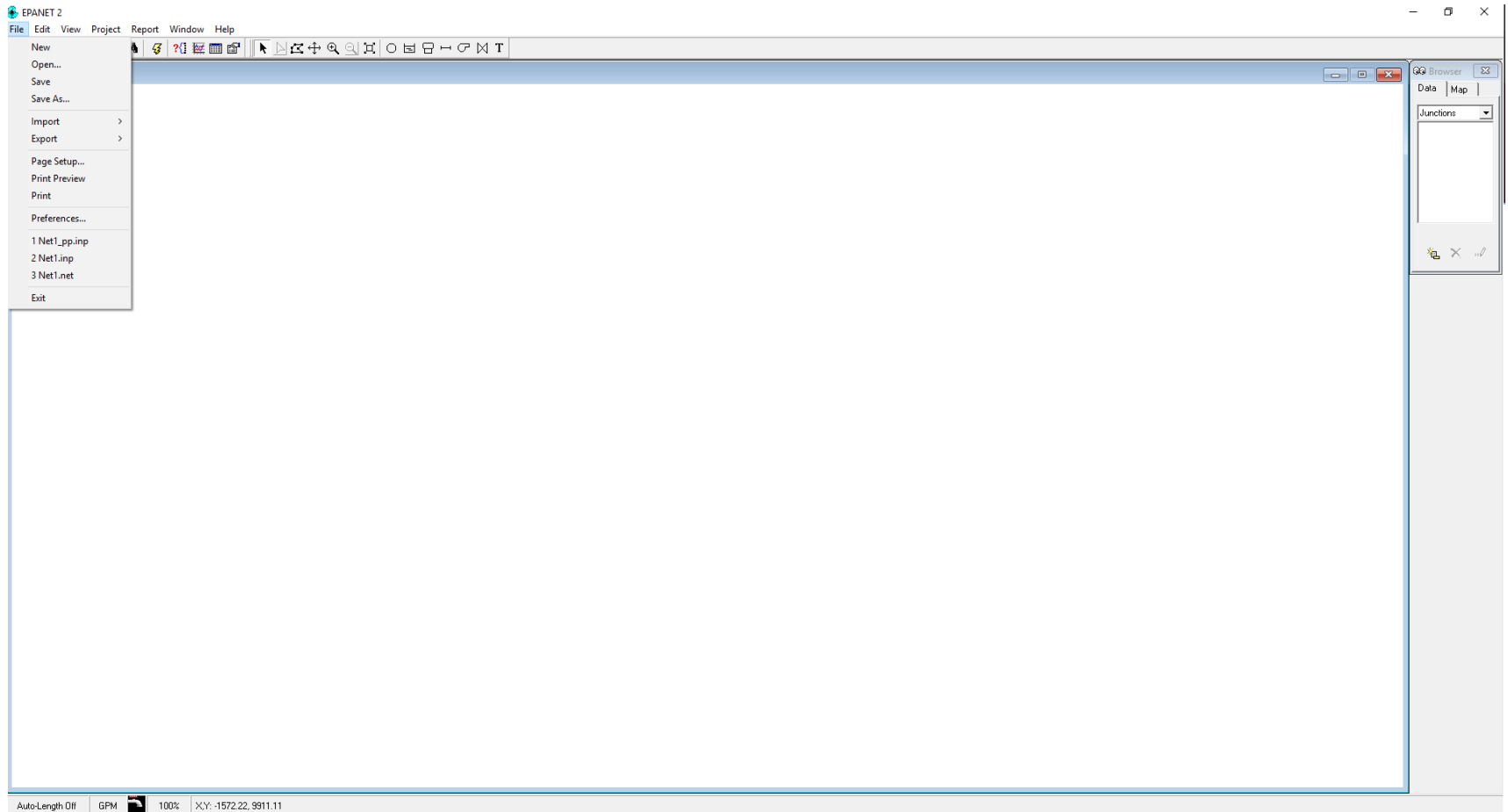
Naći čvorove u kojima je povećana potrošnja (gubitak vode) u odnosu na ono što je prvobitno pretpostavljeno u modelu

Taj gubitak vode uzrokuje neslaganje izmerenih i modeliranih pritisaka u dva čvora.

Koristi se program EPANET
Download: <https://www.epa.gov/water-research/epanet>

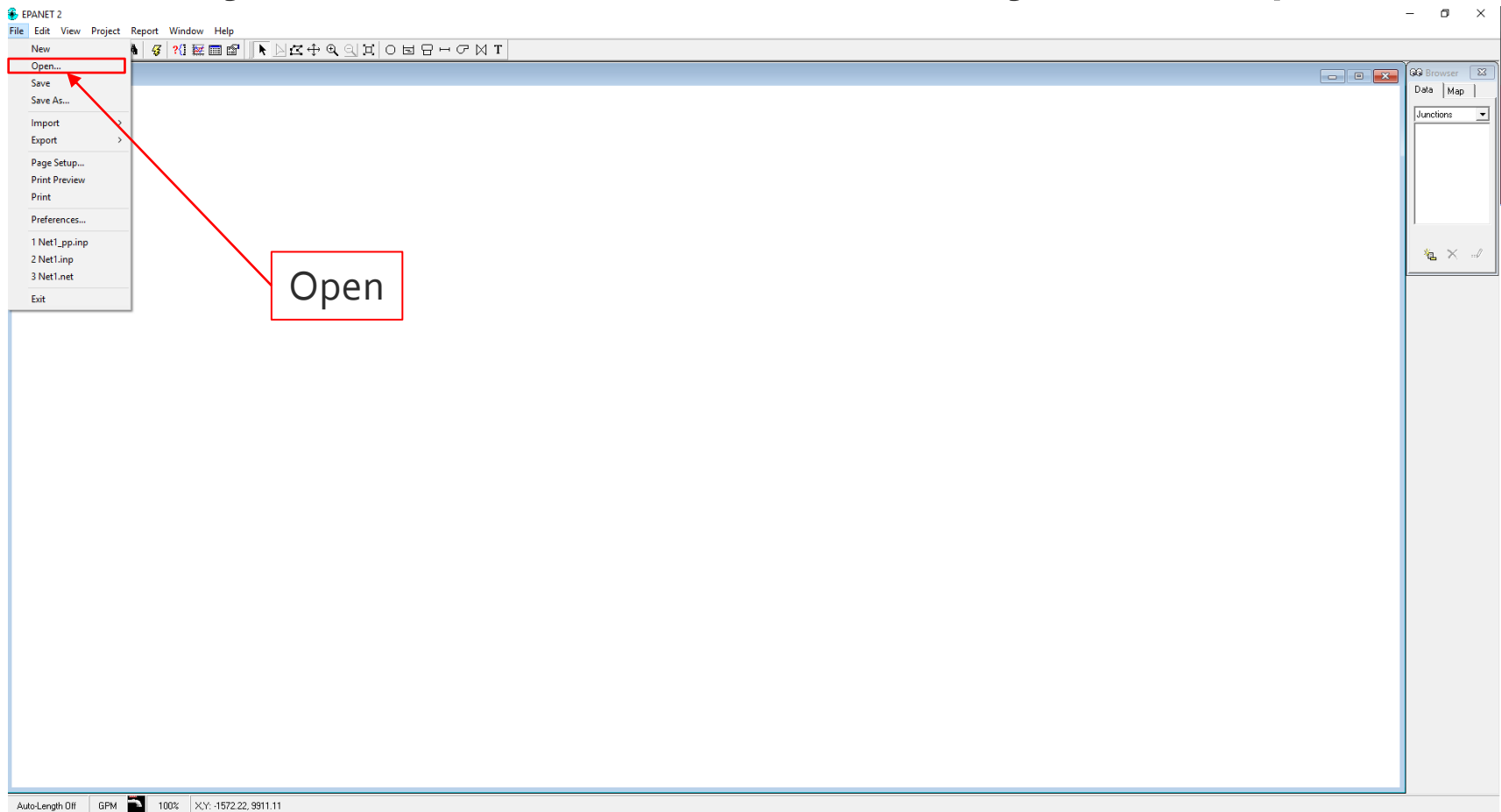
ANALIZA GUBITAKA U VODOVODU

Instalirati i pokrenuti program EPANET 2.0



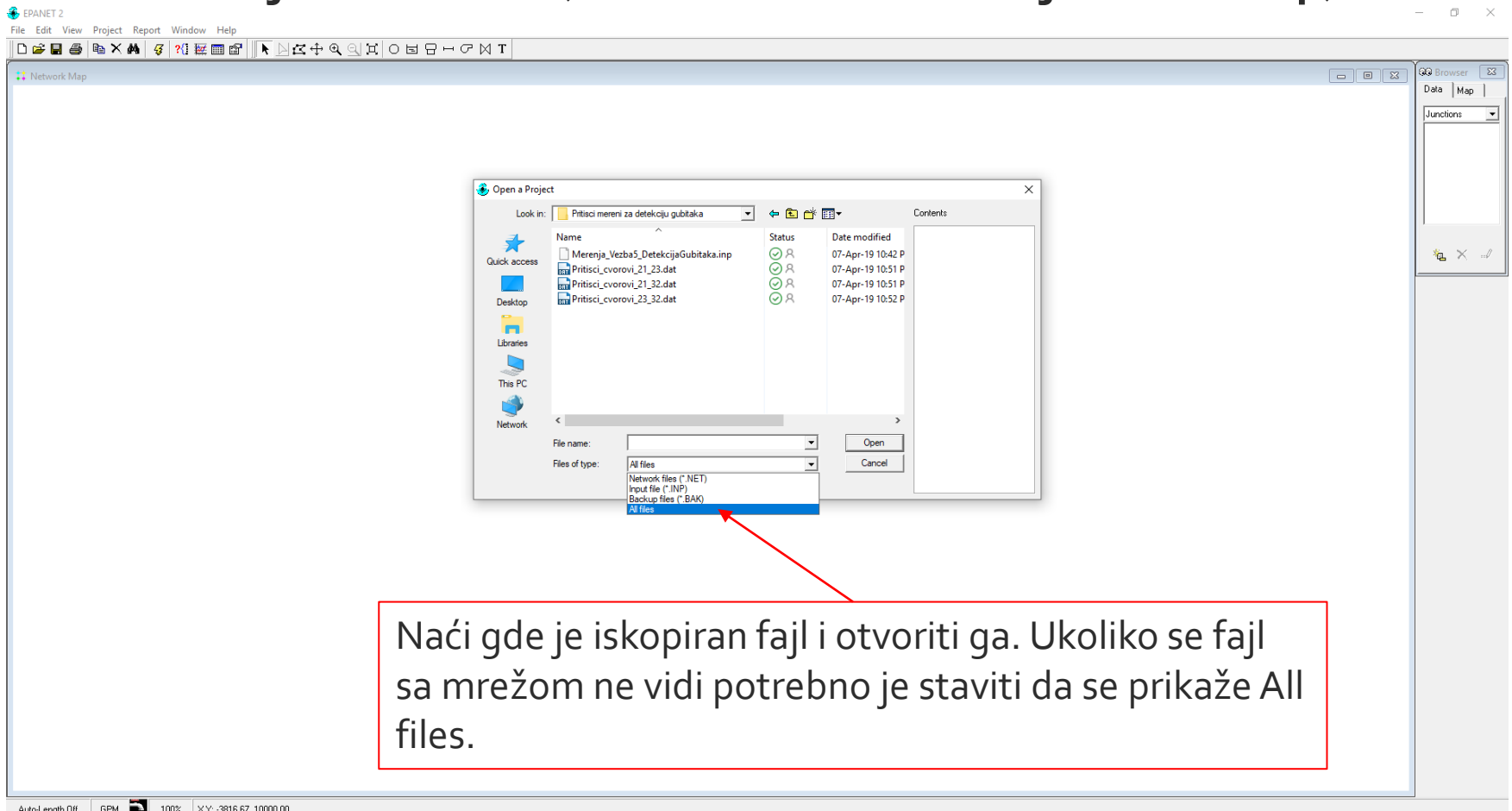
ANALIZA GUBITAKA U VODOVODU

Učitati fajl sa mrežom (može da ima ekstenziju .net ili .inp)



ANALIZA GUBITAKA U VODOVODU

Učitati fajl sa mrežom (može da ima ekstenziju .net ili .inp)



The screenshot shows the EPANET 2 interface with an 'Open a Project' dialog box. The dialog box is open to a network location and displays a list of files. The 'Files of type' dropdown menu is open, showing 'All files' selected. A red arrow points from the text box below to the 'All files' option in the dropdown menu.

Name	Status	Date modified
Merenja_Vezba5_DetekcijaGubitaka.inp	✓	07-Apr-19 10:42 P
Pritisici_cvorovi_21_23.dat	✓	07-Apr-19 10:51 P
Pritisici_cvorovi_21_32.dat	✓	07-Apr-19 10:51 P
Pritisici_cvorovi_23_32.dat	✓	07-Apr-19 10:52 P

Files of type: All files (selected), Network files (*.NET), Input file (*.INP), Backup files (*.BAK), All files

Naći gde je iskopiran fajl i otvoriti ga. Ukoliko se fajl sa mrežom ne vidi potrebno je staviti da se prikaže All files.

ANALIZA GUBITAKA U VODOVODU

Editovanje elemenata mreže

The screenshot shows the EPANET 2 interface. The main window displays a network map with a 'Source', 'Pump', and 'Tank' connected to 'Junction 12'. A red arrow points from a text box to 'Junction 12'. Another red arrow points from the 'Base Demand' value in the 'Junction 12' properties dialog box to the same junction. The dialog box shows the following properties:

Property	Value
*Junction ID	12
X-Coordinate	50.00
Y-Coordinate	70.00
Description	
Tag	
*Elevation	213.36
Base Demand	8.4635
Demand Pattern	
Demand Categories	1
Emitter Coeff.	
Initial Quality	0.5
Source Quality	
Actual Demand	#N/A
Total Head	#N/A
Pressure	#N/A
Quality	#N/A

Auto-Length Diff LPS 100% X,Y: 50.32, 69.95

Dupli klik na čvor –editovanje čvora (visinska kота, koordinate, čvorna potrošnja, ...)

Čvorna potrošnja (Base demand) je onaj parametar preko kog tražimo gubitke vode

ANALIZA GUBITAKA U VODOVODU

Editovanje elemenata mreže

The screenshot displays the EPANET 2 software interface. The main window shows a network map with a source, a pump, and a tank. A red arrow points from a text box to a pipe in the network. A dialog box titled 'Pipe 12' is open, showing the following properties:

Property	Value
*Pipe ID	12
*Start Node	12
*End Node	13
Description	254
Tag	
*Length	1609.344
*Diameter	250
*Roughness	1
Loss Coeff.	0
Initial Status	Open
Bulk Coeff.	
Wall Coeff.	
Flow	#N/A
Velocity	#N/A
Unit Headloss	#N/A
Friction Factor	#N/A
Reaction Rate	#N/A
Quality	#N/A
Status	#N/A

At the bottom of the interface, the status bar shows: Auto-Length Off, LPS, 100%, X,Y: 60.00, 69.36.

Dupli klik na cev – editovanje cevi
(dužina, prečnik, hrapavost, ...)

ANALIZA GUBITAKA U VODOVODU

Uvoz (import) izmerenih podataka

The screenshot shows the EPANET 2 software interface. The 'Project' menu is open, and the 'Calibration Data...' option is highlighted. A red box around the text 'Project\Calibration Data' has a red arrow pointing to the menu item. The main window displays a network diagram with a Source, Pump, and Tank. A 'Data Browser' window on the right shows a list of pipes with pipe 12 selected.

Pipes
10
11
12
21
22
31
110
111
112

Auto-Length Off LPS 100% XY: -14.61, 93.80

ANALIZA GUBITAKA U VODOVODU

Uvoz (import) izmerenih podataka

Pošto su mereni pritisci, onda biramo opciju da uvezemmo pritiske

Klik u polje za pritiske pa Browse

Parameter	Name of Calibration File
Demand	
Head	
Pressure	
Quality	
Flow	
Velocity	

Buttons: Browse, Edit, OK, Cancel, Help

ANALIZA GUBITAKA U VODOVODU

Uvoz (import) izmerenih podataka

Pošto su mereni pritisci, onda birmo opciju da uvezemmo pritiske

Klik u polje za pritiske pa Browse i naći gde je smešten fajl (fajl ima ekstenziju .dat)

U .dat fajlu su označeni čvorovi u kojima je meren pritisak

Parameter	Name of Calibration File
Demand	
Head	
Pressure	c:\ju gubitaka\Pritisaci_čvorovi_21_23.dat
Quality	
Flow	
Velocity	

ANALIZA GUBITAKA U VODOVODU

Pokretanje proračuna

The screenshot displays the EPANET 2 software interface. The main window shows a network map with a 'Source', 'Pump', and 'Tank' connected by pipes. A red arrow points from the 'Run' button (a lightning bolt icon) to the 'Run' button in the software's toolbar. The 'Run' button is highlighted with a white box and a lightning bolt icon.

The software window title is "EPANET 2 - Merenja_Vezba5_DetekcijaGubitaka.inp". The menu bar includes File, Edit, View, Project, Report, Window, and Help. The toolbar contains various icons for file operations, navigation, and simulation. The main window is titled "Network Map" and shows a network diagram with a 'Source', 'Pump', and 'Tank' connected by pipes. A red arrow points from the 'Run' button to the 'Run' button in the software's toolbar. The 'Run' button is highlighted with a white box and a lightning bolt icon.

The status bar at the bottom shows "Auto-Length Off", "LPS", "100%", and "XY: 46.80, 93.80".

On the right side, there is a "Browser" window showing a list of "Junctions" with values 10, 11, 12, 13, 21, 22, 23, 31, and 32. Junction 12 is selected.

ANALIZA GUBITAKA U VODOVODU

Poredjenje modeliranih i merenih pritisaka u dva čvora

The screenshot displays the EPANET 2 software interface. The main window shows a network map with a 'Source', 'Pump', and 'Tank' connected by pipes. A red arrow points from a text box labeled 'Calibration\Report' to the 'Report' menu item in the software's menu bar. The 'Report' menu is open, showing options: Status, Energy, Calibration, Reaction, Full..., Graph..., Table..., and Options... The 'Calibration' option is highlighted. On the right side, a 'Browser' window shows a list of 'Junctions' from 10 to 32, with junction 21 selected. The status bar at the bottom indicates 'Auto-Length Off', 'LPS', '100%', and coordinates 'X,Y: -24.78, 93.90'.

Calibration\Report

ANALIZA GUBITAKA U VODOVODU

Poredjenje modeliranih i merenih pritisaka u dva čvora

The screenshot displays the EPANET 2 software interface. The main window shows a network map with a 'Tank' and a 'Pum' (pump) source. A 'Calibration Report Options' dialog box is open, allowing users to configure the report. The 'Calibrate Against' dropdown menu is set to 'Pressure'. The 'Measured at Nodes' list includes nodes 21 and 23, both of which are checked. The dialog box has 'OK', 'Cancel', and 'Help' buttons. A red arrow points from a text box labeled 'Calibration\Report' to the 'Calibration' menu item in the software's menu bar. The software title bar indicates the file name 'EPANET 2 - Merenja_Vezba5_DetekcijaGubitaka.inp'. The status bar at the bottom shows 'Auto-Length Off', 'LPS', '100%', and 'X,Y: -24.78, 93.90'.

Calibration\Report

ANALIZA GUBITAKA U VODOVODU

Poredjenje modeliranih i merenih pritisaka u dva čvora - *RMSE*

EPANET 2 - Merenja_Vezba5_DetekcijaGubitaka.inp

File Edit View Project Report Window Help

Network Map

Calibration Report - Pressure

Statistics Correlation Plot Mean Comparisons

Calibration Statistics for Pressure

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
21	24	80.58	80.55	0.043	0.051
23	24	83.22	83.21	0.046	0.056
Network	48	81.90	81.88	0.045	0.054

Correlation Between Means: 1.000

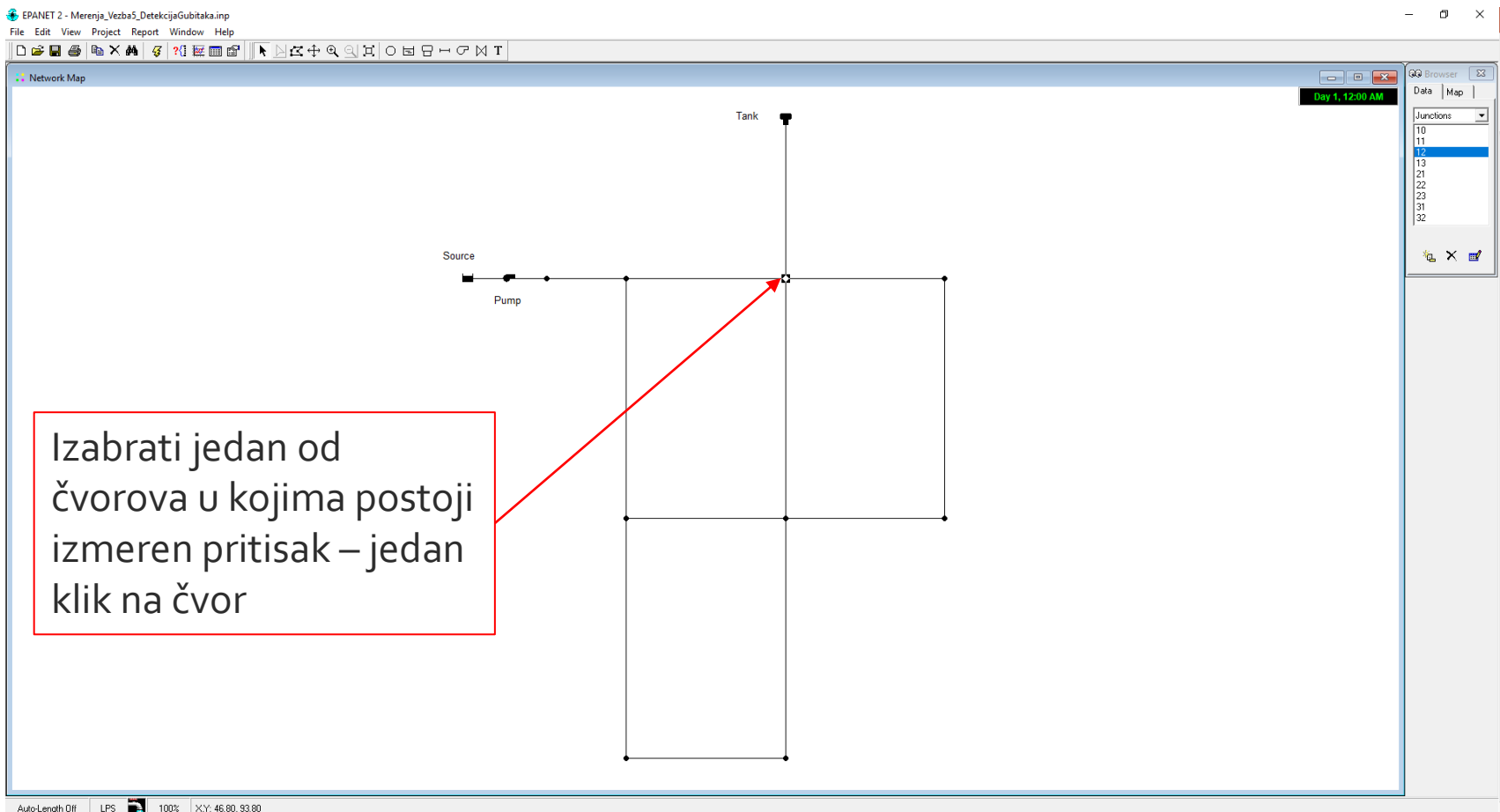
Srednja vrednost RMSE za dva merna mesta

Ako nije zadovoljen kriterijum menja se potrošnja u čvorovima kao na slajdu #12 i ponovo pušta proračun dok se ne dobije da je RMSE manji od zahtevane vrednsoti.

Auto-Length Off LPS 100% X,Y: -24.78, 93.90

ANALIZA GUBITAKA U VODOVODU

Stampanje dijagrama – vremenske serije (time series)



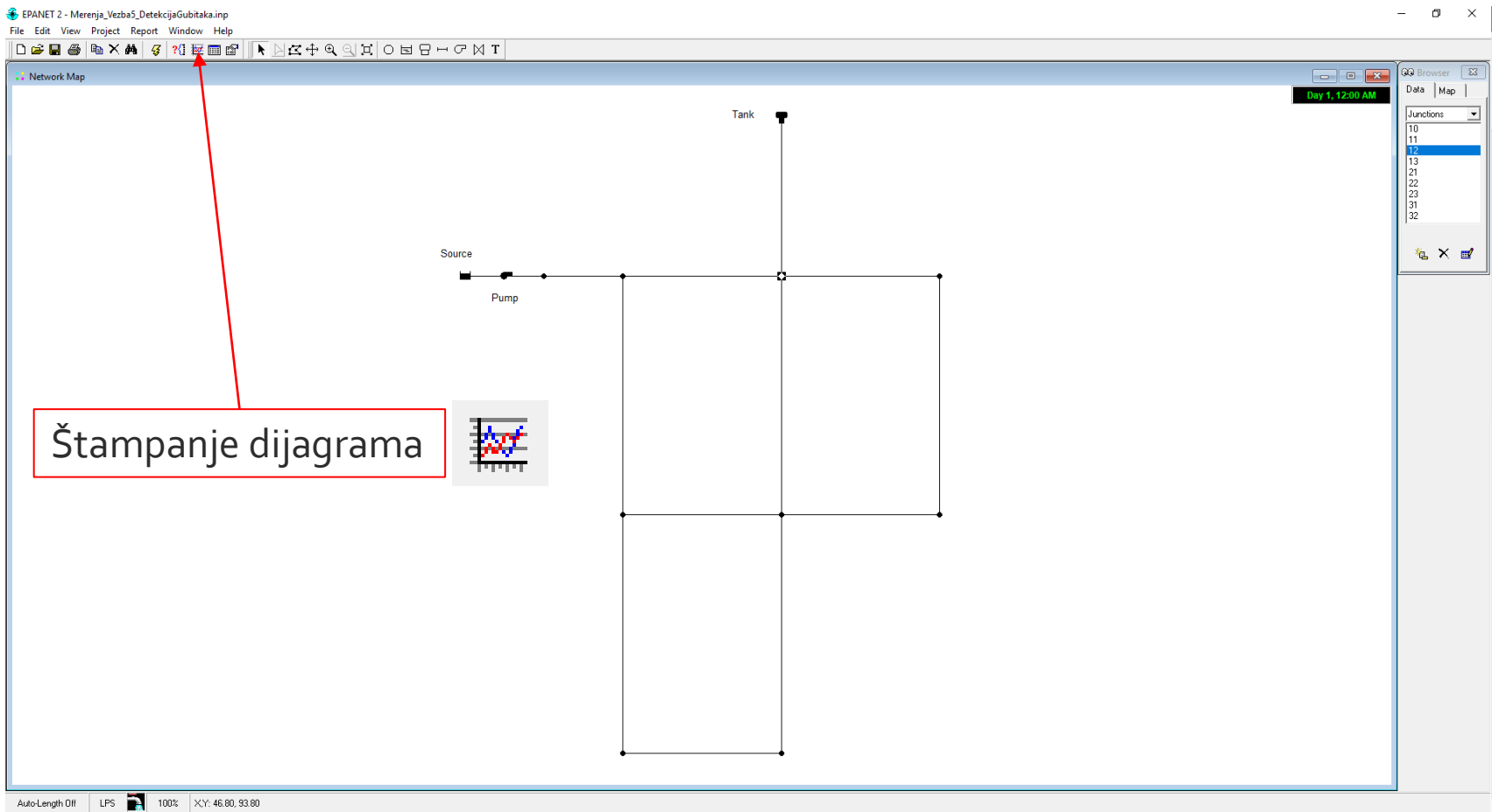
The screenshot displays the EPANET 2 interface for a project named "Merenja_Vezba5_DetekcijaGubitaka.inp". The main window shows a "Network Map" with a grid of pipes. A "Source" is located on the left, and a "Pump" is positioned below it. A "Tank" is located at the top center. A red arrow points from a text box to a specific junction in the network. The right-hand side of the interface includes a "Data Browser" window with a "Junctions" list containing values 10, 11, 12, 13, 21, 22, 23, 31, and 32. The "Day 1, 12:00 AM" is displayed in the top right corner of the map area.

Izabrati jedan od čvorova u kojima postoji izmeren pritisak – jedan klik na čvor

Auto-Length Off LPS 100% XY: 46.80, 93.80

ANALIZA GUBITAKA U VODOVODU

Stampanje dijagrama – vremenske serije (time series)



The screenshot displays the EPANET 2 software interface. The main window shows a network map with a 'Source', 'Pump', and 'Tank' connected by pipes. A red arrow points from a text box to the 'Print Diagrams' icon in the toolbar. The 'Print Diagrams' icon is a small window showing a time series plot with multiple colored lines. The status bar at the bottom indicates 'Auto-Length Off', 'LPS', '100%', and 'XY: 46.80, 93.80'.

EPANET 2 - Merenja_Vezba5_DetekcijaGubitaka.inp

File Edit View Project Report Window Help

Network Map

Day 1, 12:00 AM

Junctions

10
11
12
13
21
22
23
31
32

Štampanje dijagrama

Auto-Length Off LPS 100% XY: 46.80, 93.80

ANALIZA GUBITAKA U VODOVODU

Stampanje dijagrama – vremenske serije (time series)

Izabrati da se za čvor štampa vremenska serija

Izabrati promenljivu koja će biti na dijagramu - pritisak

OK

Graph Selection

Graph Type

- Time Series
- Profile Plot
- Contour Plot
- Frequency Plot
- System Flow

Object Type

- Nodes
- Links

Nodes to Graph

- 21

Parameter

- Elevation
- Base Demand
- Initial Quality
- Demand
- Head
- Pressure**
- Chlorine

Buttons: Add, Delete, Move Up, Move Down, OK, Cancel, Help

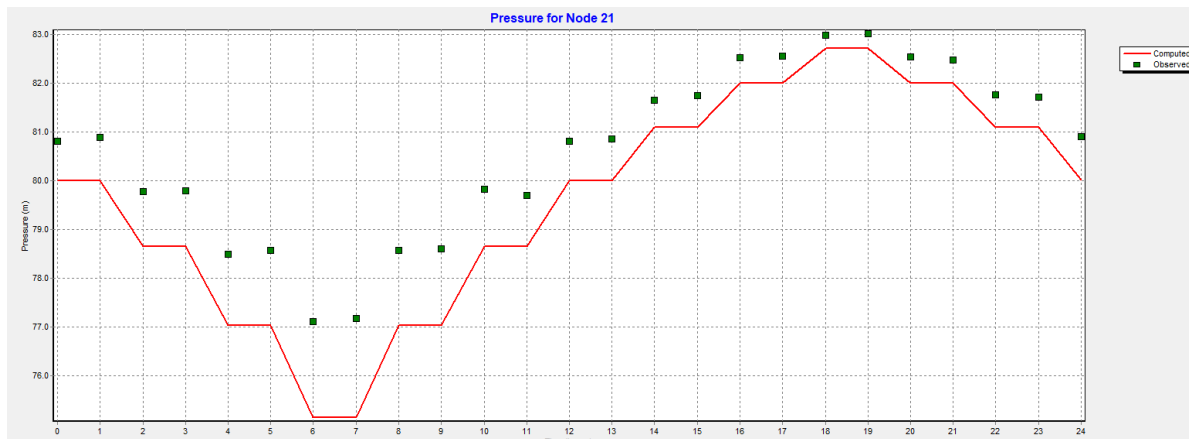
Junctions: 10, 11, 12, 13, 21, 22, 23, 31, 32

Day 1, 12:00 AM

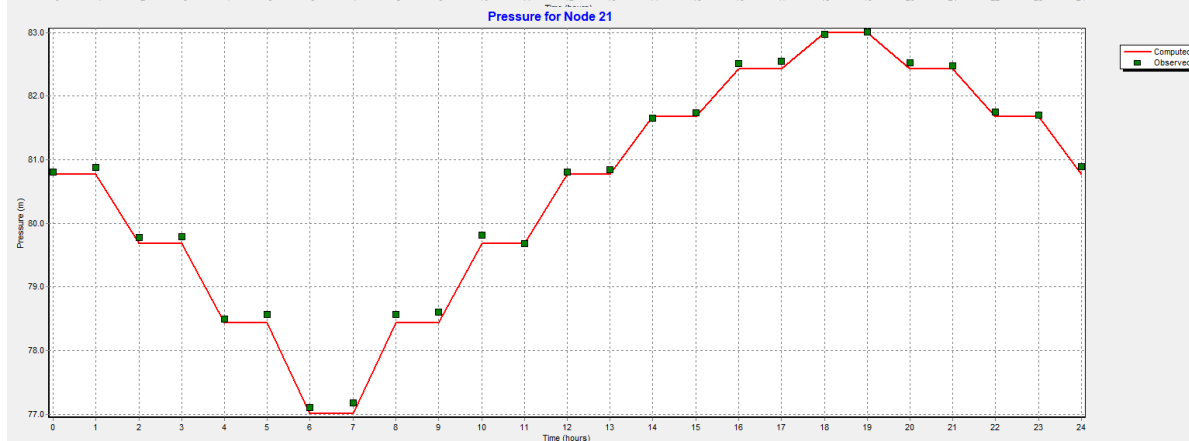
Auto-Length Off LPS 100% XY: 46.80, 93.80

ANALIZA GUBITAKA U VODOVODU

Stampanje dijagrama – vremenske serije (time series)



Loši rezultati



Dobri rezultati

ANALIZA GUBITAKA U VODOVODU

Za više informacija o programu EPANET 2.0

<https://nepis.epa.gov/Adobe/PDF/P1007WWU.pdf>

<https://www.youtube.com/watch?v=d58213qosYM&list=PLmWwzbjnLbQ1ouggBX6E6RBx5QBJTsBTL&index=1>

Povezivanje EPANET-a i MATLAB-a (može da posluži za automatsku detekciju gubitaka)

<https://www.youtube.com/watch?v=7fQTeZomH8Q>