Monitoring Water Distribution Systems

Teacher

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<table>
<tr><th colspan="3">Phenomenon

Where should we place monitors within a water distribution system to efficiently detect potential contaminants in the water supply?</th></tr>
<tr><td colspan="3">Next Generation Science Standard (NGSS)

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.</td></tr>
<tr><td>Disciplinary Core Idea (DCI)</td><td>Science and Engineering Practice (SEP)</td><td>Cross Cutting Concept (CCC)</td></tr>
<tr><td>LS2.C.2: Ecosystem Dynamics, Functioning, and Resilience:

Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.</td><td>Constructing Explanations and Designing Solutions:

Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</td><td>Stability and Change:

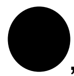
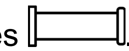
Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
</table>

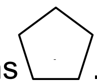
Pipeline Panic Game

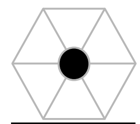
A two-player game where the Defender monitors chlorine level in a water distribution system, while the Attacker tries to raise them to a dangerous level.

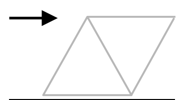
Set Up:

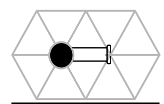
1. Determine roles. The person who drank water the most recently is the Defender. The other player is the Attacker.

2. The Defender cuts out reservoirs , monitor , and pipes .

   The Attacker cuts out chlorine tokens .

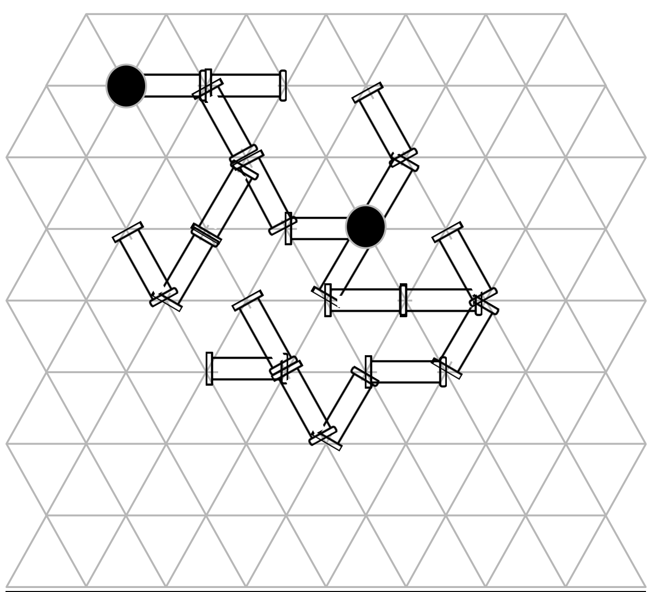
3. The Defender randomly places both reservoirs on any junction. 

   Junctions are points where lines meet. 

4. The Attacker places a pipe on any line leading away from a reservoir: 

5. The Defender and the Attacker take turns placing the remaining 19 pipes. Pipes must connect to each other or a reservoir.

   Below is an example of what a final water distribution system may look like:



Game Play:

Defender's Turn

Choose one of the following actions:

- Add or move a monitor to any junction that has a pipe or reservoir.

  When a monitor is placed, flip over a chlorine token to reveal its value.

- Remove one face up or face down chlorine token.

You win if:

- The Attacker runs out of chlorine tokens, and
- The total chlorine value in the water distribution system remains at or under 4.

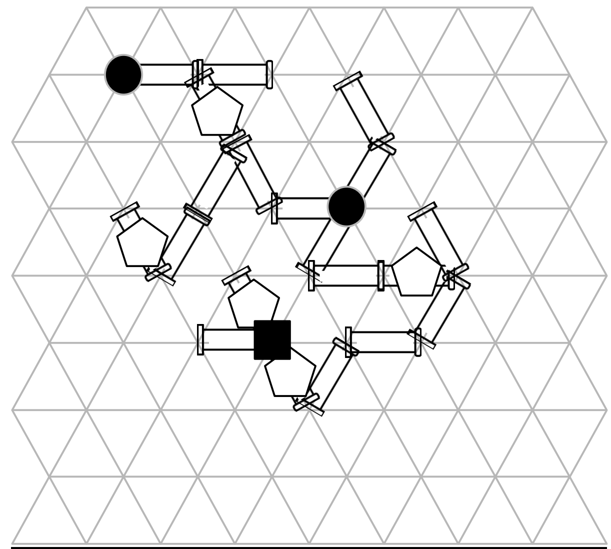
Attacker's Turn

Take the following action:

- Place two chlorine tokens face down on any pipe(s).

You win if:

- The total chlorine value in the water distribution system exceeds 4. See an example to the right.



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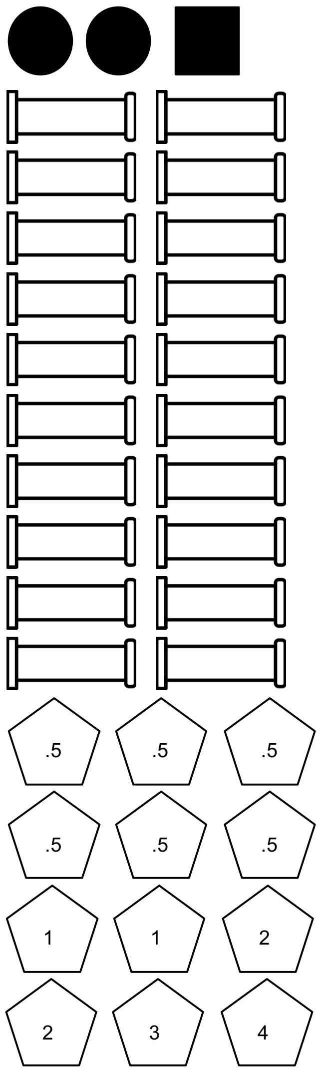
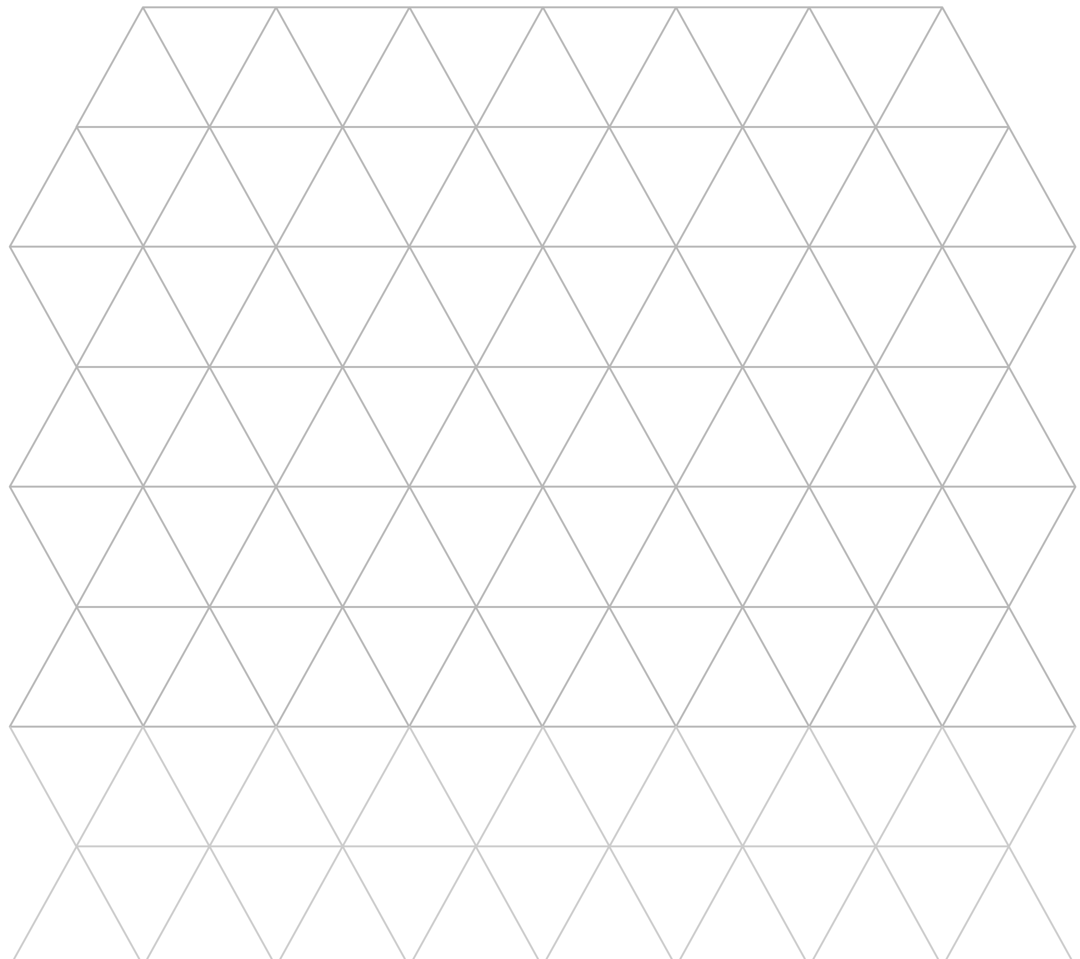
<u>Pipeline Panic Game Board and Pieces</u>

(one handout per team of two players)





Monitoring Water Distribution Systems

Background Information

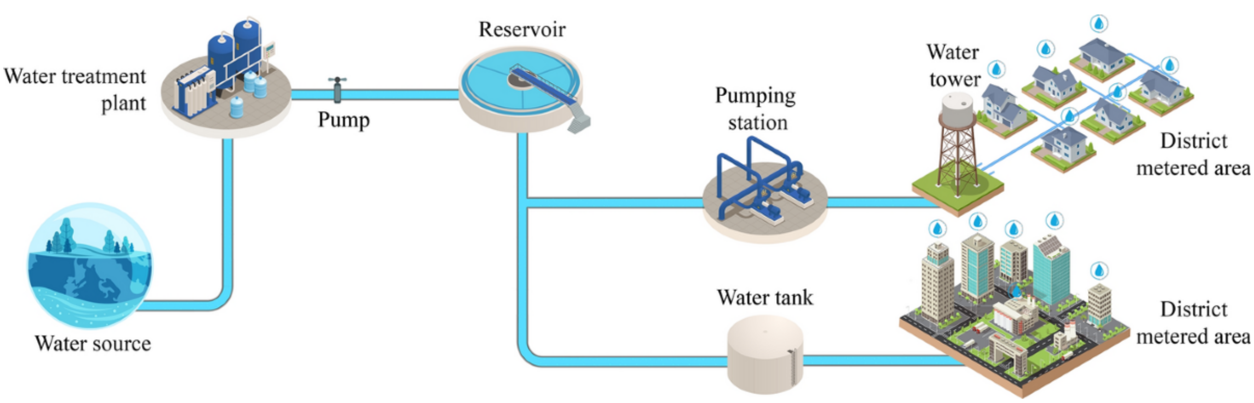
The Jardine Water Purification Plant in Chicago is the largest water treatment facility in the world. It is responsible for cleaning and distributing safe drinking water from Lake Michigan to millions of residents.

One of the key steps in this process is adding chlorine to the water, which makes it safe to drink. The ideal chlorine level for drinking water is between 0.2 and 4 parts per million (ppm). The chlorine kills harmful bacteria, viruses, and other pathogens that could make people sick.

However, if too much chlorine is added, it can lead to health problems such as eye and skin irritation. High concentrations of chlorine may cause more serious effects like damage to the respiratory system or internal organs. Chlorine can also bond with chemicals in pipes to create other contaminants that pose additional health risks. Water treatment plants must be precise in adding the correct amount of chlorine to the water supply: enough to kill harmful bacteria, but not so much as to create health risks.

Monitor Placement Strategies

Monitors are added to water distribution systems to continuously check for water quality, pressure, and potential contaminants. Monitors help ensure that the water remains safe and reliable as it travels to homes and businesses. These monitors detect problems such as leaks, drops in pressure, or the presence of harmful substances.



Taloma, R.J.L., Cuomo, F., Comminiello, D. et al. Machine learning for smart water distribution systems: exploring applications, challenges and future perspectives. Artif Intell Rev 58, 120 (2025). https://doi.org/10.1007/s10462-024-11093-7

To efficiently detect potential contaminants in a water distribution system, monitors (or sensors) should be placed based on scientific principles of water flow, risk assessment, and contaminant behavior. Several effective placement strategies are frequently used:

1. Placing monitors at the water source—such as a lake, river, or groundwater well—allows early detection of contaminants before they enter the distribution system. This helps identify pollution from natural or human activities and acts as the first line of defense in protecting public health.
2. Monitors should be placed where water exits treatment plants and enters the distribution network. These points confirm that the water leaving the plant meets safety standards, providing a clean baseline for comparison with downstream water quality.
3. In areas with large populations or vulnerable groups like schools or hospitals, monitors are essential for protecting those most at risk. Placing sensors in these zones ensures quick detection of problems where they could affect the most people.
4. Water mains often intersect or mix water from multiple sources. Monitors at these junctions help detect contamination that could quickly spread through large parts of the system due to turbulent mixing and directional flow changes.
5. Areas with low flow or dead ends can allow water to stagnate, which may promote bacterial growth or allow contaminants to settle. Monitoring in these zones helps detect localized issues that may not be seen elsewhere in the system.
6. Random or representative households and businesses should be monitored to check the water quality that consumers actually receive. This ensures that all treatment and delivery processes are working correctly throughout the system.

Case Study

The image below shows a simplified map of a city's water distribution system.

The squares represent reservoirs, which are large storage containers or tanks that hold treated water before it is distributed to consumers.

The dots represent junctions that are connection points in the water distribution system where two or more pipes meet or branch off to provide water to neighborhoods and communities.

The lines represent pipes that transport water from reservoirs through the network to homes, businesses, and other endpoints.

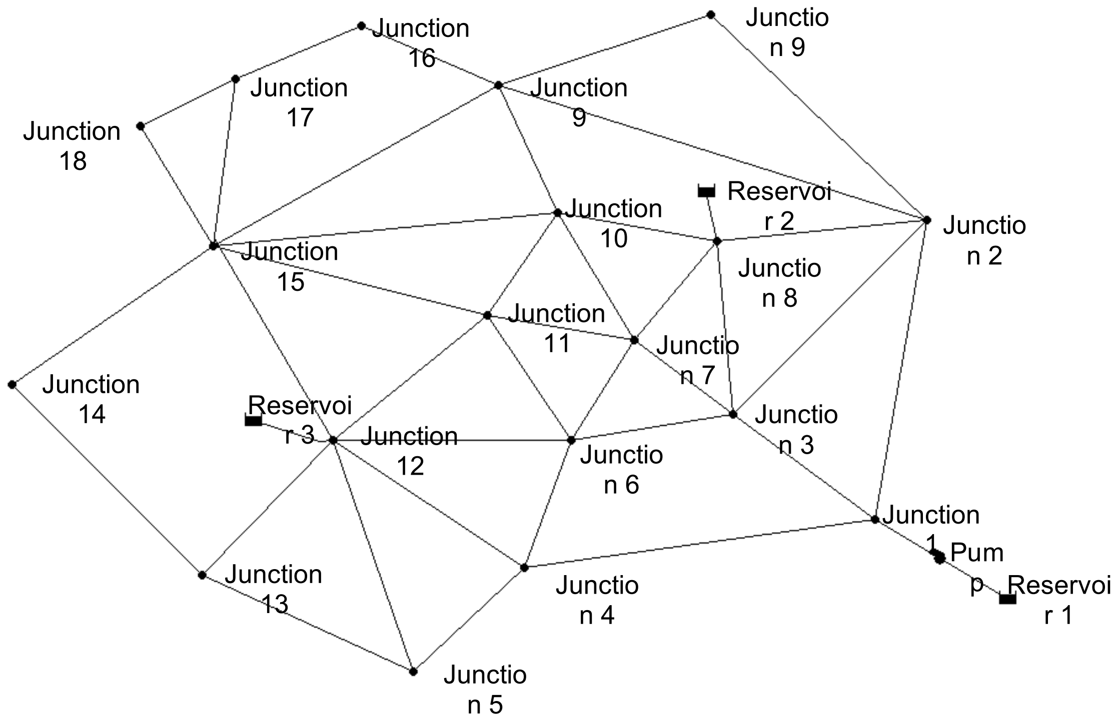


Table 1. Chlorine level in parts per million (ppm) found in junctions by day of the week.

Junction	Monday	Tuesday	Wednes.	Thusday	Friday	Saturday	Sunday
1	0.20	0.20	0.20	0.20	0.20	0.20	0.20
2	0.25	0.33	0.25	0.20	0.22	0.30	0.20
3	2.10	3.00	2.55	2.10	3.30	3.10	2.20
4	0.33	0.25	0.20	0.22	0.3	0.20	0.25
5	0.25	0.20	0.22	0.30	0.20	0.25	0.33
6	2.55	2.10	3.30	3.10	2.20	2.10	3.00
7	1.60	1.50	1.35	1.45	1.80	1.20	0.85
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	2.60	2.45	2.20	2.90	3.10	2.60	2.80
10	2.20	2.90	3.10	2.60	2.80	2.60	2.45
11	3.10	2.60	2.80	2.60	2.45	2.20	2.90
12	3.00	3.00	3.00	3.00	3.00	3.00	3.00
13	3.90	3.85	3.95	3.65	3.40	3.95	3.60
14	4.10	4.50	5.00	4.40	4.60	5.50	4.30
15	3.65	3.40	3.95	3.60	3.90	3.85	3.95
16	2.95	2.70	2.80	3.10	3.65	3.40	3.10
17	2.55	2.10	3.30	3.10	2.20	2.10	3.00
18	2.10	3.00	2.55	2.10	3.30	3.10	2.20

Monitoring Water Distribution Systems CER (Mild)

Directions: Using the background information, monitor placement strategies, and case study provided, write a CER on the question below:

Where should we place monitors within a water distribution system to efficiently detect potential contaminants in the water supply?

Claim

One example of an anthropogenic change to the environment is ___________________

____.

This human activity disrupts the ecosystem by __________________________________

____.

This human activity threatens the survival of some species by ____________________

____.

A solution to reduce the impact on the environment is installing a monitor at junction

____.

Evidence

According to _____________________, conditions remain stable if _________________
cite source

____
cite qualitative (descriptive) evidence

____.

Additionally, according to _____________________, conditions remain stable if ______
cite source

____
cite quantitative (numerical) evidence

____.

Conditions change if, according to ____________________, _____________________
cite new source

____.
cite qualitative (descriptive) evidence

____.

Additionally, conditions change if, according to ____________________, ___________
cite new source

____.
cite qualitative (descriptive) evidence

____.

Reasoning

A solution to reduce the impact on the environment is installing a monitor at junction

____.

This solution is effective because it uses monitor placement strategy #________, which

____
cite scientific knowledge

____.

If this solution is implemented, it will ____
prediction

____.

In contrast, monitor placement strategy #________ would not be effective because ___

____
cite scientific knowledge

____.

If this solution was implemented, it will ______________________________________
prediction

____.

<u>Monitoring Water Distribution Systems CER</u> (Medium)

Directions: Using the background information, monitor placement strategies, and case study provided, write a CER on the question below:

Where should we place monitors within a water distribution system to efficiently detect potential contaminants in the water supply?

Claim ☐describe an **anthropogenic change** to the environment. ☐describe disruption to **ecosystem** ☐describe threat to **species survival** ☐propose **solution** to reduce human impact	______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________.
Evidence ☐cite **qualitative** evidence for **stable** conditions ☐**quantitative** evidence for **stable** conditions ☐cite **qualitative** evidence for **changing** conditions ☐**quantitative** evidence for **changing** conditions	______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________.

Reasoning ☐**describe** a solution to a complex, real-world problem ☐**design, evaluate, and refine** a solution to a complex real-world problem. ☐use **scientific knowledge** ☐**predict the result** of my solution	.

1. **<u>Monitoring Water Distribution Systems CER</u>** (Spicy)

Directions: Using the background information, monitor placement strategies, and case study provided, write a CER on the question below:

Where should we place monitors within a water distribution system to efficiently detect potential contaminants in the water supply?

HS-LS2-7. Assessment Rubric

	4/4: Exceeding Expectations (100%)	**3/4:** Meeting Expectations (88%)	**2/4:** Approaching Expectations (76%)	**1/4:** Emerging Understanding (64%)
DCI: LS2.C.2: Ecosystem Dynamics, Functioning, and Resilience	☐I proposed a **solution** to reduce the impact of the **anthropogenic change** on the environment.	☐I described how an **anthropogenic change** to the environment can **disrupt an ecosystem** and **threaten the survival of some species**.	☐I described how an **anthropogenic change** to the environment can **disrupt an ecosystem**.	☐I described an **anthropogenic change** to the environment.
CCC: Stability and Change	☐I cited **multiple** pieces of **qualitative and quantitative** data from a **variety of sources** to explain how conditions **change.**	☐I cited **qualitative and quantitative** data to explain how conditions **change.**	☐I cited **qualitative and quantitative** data to explain how conditions remain **stable.**	☐I cited **qualitative** data to explain how conditions remain **stable.**
SEP: Constructing Explanations and Designing Solutions	☐I **predicted the result** of my solution to a complex real-world problem.	☐I used scientific knowledge to **design, evaluate, and refine** a solution to a complex real-world problem.	☐I **designed, evaluated, and refined** a solution to a complex real-world problem.	☐I **described** a solution to a complex real-world problem.