Teacher Guide (Page 1-6) & Rubric (7-8) – Module 6 HOA A: Water-Budget Ledger

This HOA directly supports Lesson A's essential question, "How is space reshaping where and how we grow food?", by having students compare water budgets across urban, peri-urban, and rural production examples. Framing this as a design task reinforces Module 6's focus on circular systems, asking students to treat water budgets as levers for reducing waste, improving resilience, and planning climate-smart growing spaces.

Activity Overview:
In **Module 6's first Hands-On Activity**, students set up and monitor a **water-budget ledger** by growing one plant with **drip irrigation in soil** and another in a **hydroponic (soilless) setup**. Over ~2–3 weeks, they record daily water inputs and outputs to compare **water-use efficiency** between the two systems. This activity embodies the theme "**From Balcony to Back-Forty**" by bridging **urban and rural water practices:** hydroponics represents a small-scale, controlled urban method (e.g., a balcony or rooftop garden), and drip irrigation represents a larger-scale, efficient rural farming method. Students practice **systems thinking** by tracking water flows (inputs, outputs, storage) in each mini-system and connecting these findings to broader sustainability concepts in agriculture.

Learning Objectives: By the end of this activity, students will be able to:

- **Quantitatively compare** water usage between a soil-based and a hydroponic growing system for the same type of plant.
- **Calculate and interpret water-use efficiency** (e.g., amount of water used per unit of plant growth) and identify which system is more efficient under the given conditions.
- **Explain, using systems thinking,** where water goes in each system (plant uptake, soil retention, runoff, evaporation) and how system design affects these pathways.
- **Connect design to context:** Discuss why drip irrigation is suited for larger land (rural farms) and hydroponics for confined spaces (urban farming), including trade-offs in infrastructure, maintenance, and resource use.
- **Apply sustainability principles** by suggesting improvements to reduce water waste in either system (e.g., capturing runoff, recycling water) and recognizing the importance of water conservation across agri-food settings.

Duration: *Initial Setup:* Approximately 30 minutes (to introduce the activity and have students assemble both systems). *Ongoing Monitoring:* ~5–10 minutes **daily** for 2–3 weeks (students check water levels, add water, and log data – can be done at start or end of class or as a bell-ringer/bell-ending activity). *Final Session:* ~30 minutes to compile results, do calculations, and discuss findings (could be part of a lesson or separate HOA debrief).

Student Grouping: Recommend **pairs or groups of 3**. Small groups ensure everyone has a role (measuring, pouring, recording data, and observations) and encourage collaboration. If materials are limited, groups of 3 are fine; if plentiful, pairs give more hands-on time per student. Ensure each group has **both** a soil setup and a hydro setup to compare. Option: if space is an issue, half the groups could do soil and half do hydro, and then compare data, but ideally each group does both for direct experience.

Materials Needed (for the class):

- **Plants/Seeds:** Fast-growing seedlings (leafy greens like lettuce or herbs) or seeds that germinate quickly. We need two per group (one for soil and one for hydro). Tip: Using identical plants for comparison improves accuracy.
- **Soil and Pots:** Small pots (4–6 inches) and potting soil for each group's soil plant. Trays or shallow dishes to catch runoff.
- **Drip Irrigation Supplies:** Could be a 500 mL plastic bottle with a pinhole (for slow drip) or actual drip emitters/tubing if available. Simpler: fill the bottle, invert it over a pot with a pinhole to simulate a drip. (Pre-poke pinholes for students if using bottles to avoid injury.)
- **Hydroponic Setup:** Small jars, cups, or plastic containers (one per group) to hold water. A way to support the plant (net pots, foam, or even a hole in the lid that the plant can sit in so roots dangle in water). Hydroponic nutrient solution or a very dilute all-purpose fertilizer to add to water (optional but recommended for plant health). Markers to mark the water level.
- **Measuring Devices:** Graduated cylinders, measuring cups, or large syringes marked in milliliters are used for each group to measure the water added accurately. (They should measure water input/output to at least the nearest 5–10 mL for reasonable accuracy.)
- **Rulers/Tape Measures:** For tracking plant height or growth over time (at least one per group).
- **Personal Protective Equipment (PPE):** Generally minimal – perhaps gloves for handling fertilizer or soil if desired, paper towels for spills. Safety goggles not really needed unless using fertilizer solutions in powder form.
- **Data Collection Sheets:** One Water-Budget Ledger worksheet per student or per group (if they are submitting one set of data per group). Alternatively, a notebook designated for daily records.

Teacher Preparation & Setup:

- **Before class:** Gather and set up a materials station. Pre-fill some water containers, have soil and plants ready, etc. If using DIY drip (bottle with pinhole), prepare those bottles ahead of time (e.g., use a thumbtack to poke a small hole near the cap or in the cap). Test one to ensure water drips slowly, not pours.
- **Mock Example:** Consider setting up one example of each system yourself before the students do, to troubleshoot any issues (e.g., how to support a plant in the hydro jar). This also provides a demo to showcase to the class.
- **Safety check:** Identify a stable area in the classroom for each group's setups. Ideally, place trays under everything to catch spills. If possible, keep hydroponic jars covered or in a place with minimal direct light to minimize algae growth (or let that be a learning point).
- **Plan for monitoring:** Decide when during each day students will tend to their plants (e.g., at the beginning of class, end of class, or during a lab period). Consistency is key for good data. If school breaks or weekends intervene, you might assign some students to check plants or adjust the schedule (or water generously before a weekend and record it, noting the gap).
- **Video:** Cue up the **YouTube tutorial (Water-Budget Ledger How-To)** if you plan to show it. This 5–10 minute video (placeholder link) demonstrates how to assemble the drip and hydro systems. It can save time and clarify the setup steps for visual learners.

Introduction (Systems Thinking Framing):
Begin by contextualizing the activity within the **urban–rural gradient**: "In cities, space is tight and people use creative systems like hydroponics to grow food with minimal soil and water. In rural farms, techniques like drip irrigation help save water across acres of crops." Emphasize that both are systems with **inputs, outputs, and feedback**. Prompt students to consider: *"Where does the water go after we water a plant?"* This primes them to think in terms of water flow (the plant takes some, some evaporates, some might drain away). Emphasize that managing this flow is crucial to achieving sustainable agriculture. This activity is essentially a **mini water audit** for two systems. By treating water like money in a ledger, students practice tracking resources – a core sustainability skill. Remind them that **every drop counts**, whether on a rooftop garden or a farm field.

Skills Focus: This HOA develops several core skills and scientific practices:

- **Data Collection & Measurement:** Students will measure water volumes accurately each day, instilling discipline in daily observation and record-keeping.
- **Quantitative Reasoning:** They will perform simple calculations (summing daily inputs, subtracting runoff, comparing totals, possibly calculating ratios for efficiency) – applying math to a real-world context.
- **Experimental Design & Fair Testing:** Students ensure that both plants have similar conditions, aside from the soil versus hydro difference, learning about controlling variables and making fair comparisons.
- **Systems Thinking:** By mapping water inputs and outputs, students view each setup as a system. They consider boundaries (the pot versus the closed container) and how water cycles within or escapes the system, linking to broader concepts of the water cycle.
- **Critical Thinking & Reflection:** Through guided questions, they interpret their results, hypothesize reasons for differences, and suggest improvements – connecting their hands-on findings to sustainability challenges (how to grow more food with less water).
- **Collaboration:** Working in teams, they must coordinate tasks and share insights, mirroring real scientific teamwork and fostering communication skills.

Procedure & Facilitation:

1. **Launch (Day 0):** Introduce the challenge: "We're going to grow the same plant in two ways and see which uses water smarter." If using the video, play it now or demonstrate one soil pot and one hydro jar setup in front of the class. Ensure students understand the mechanics: how the drip bottle works, what counts as "runoff," how to check hydro water levels, etc. Hand out the Student Instructions and Data Sheets.

    - **Tip:** Ask a few quick predictive questions to engage them (e.g., "Who thinks the hydroponic system will use less water? Why?") but don't give away answers. This can spark curiosity.

2. **Group Setup:** Organize students into their groups and have them gather materials. Circulate to assist with planting the seedling in soil and setting up the drip bottle position (it might be propped or taped so it drips into the soil). For hydro, help them secure the plant (some teachers use a piece of foam or even a crumpled foil "donut" to hold the plant in the jar opening). Ensure each group marks the initial water level on the hydro container (so they know how much to refill).

- Emphasize measuring water with the cups/syringes – they should not just pour arbitrarily. Every addition of water must be recorded like a transaction.

3. **Initial Measurements:** Once the setups are complete, have students perform the initial watering and record the **Day 0 data** together. Help them read the meniscus and record volumes properly. If runoff occurs for the soil, show how to pour it into a graduated cylinder to measure it. This initial training will set the tone for accurate data all along.

4. **Daily Routine (Days 1–X):** Establish a routine time for daily checks. For example, during the first 5 minutes of class, one member obtains the group's measuring tool and waters the soil plant, while another measures the runoff, and so on. Students log data on their sheet. You should remind or even allocate roles (rotating who measures vs. records each day to ensure engagement).

   - Encourage consistency: use the same time of day, add water slowly to avoid sudden gushes of runoff, etc.
   - If a day is skipped (e.g., a weekend), instruct them on how to account for it (e.g., water a bit extra before the break and note "no data" for that date, or if someone comes in to care for the plants). It's okay – just have them note any irregularities.

5. **Monitoring & Guidance:** As students collect data, roam the room to answer questions or provide troubleshooting assistance. Common issues:

   - Drip bottle empties too fast or not at all: the hole may be too big or clogged – assist in adjusting the size or clearing the blockage.
   - Hydro plant wilting: perhaps not enough oxygen in water or missing nutrients – you might gently aerate or add a pinch of nutrients and explain why the hydro needs nutrients added. This can be a mini-lesson in itself.
   - Remind students to keep track of every drop – if a lot of water is collecting as runoff, discuss whether they should water more slowly or in smaller volumes at a time. It's a learning process.

6. **Mid-Point Check-In:** About a week in, hold a brief discussion: "What trends are you seeing?" Have groups share if one system seems to need more water. This keeps them engaged and thinking (and can tie back to Lesson content about climate or efficiency). It's also a chance to troubleshoot any groups that have very off-track results (e.g., a dead plant or consistently waterlogged soil – use it as a learning moment to adjust their approach).

7. **Final Data Collection (Last Day):** When plants have grown or the time is up, instruct the groups to stop and take final measurements. Perhaps coordinate a "harvest day" where they measure final plant heights or biomass. Ensure everyone calculates their totals correctly – you may want to provide a simple template on the board (e.g., sum of column A, sum of column B, etc.). If math skills vary, consider pairing groups or walking through one example as a class.

8. **Student Analysis:** Have students complete the reflection questions on the worksheet. You can complete this as a written assignment or participate in a group discussion. If time permits, a **think-pair-share** approach works well: students answer individually, then compare their responses with their group, and finally discuss as a class. Key questions to ensure are addressed: Which system used less water? Why? How do these small systems

relate to real farming methods? What would they change or improve?

- Option: Ask each group to create a quick poster or slide summarizing their data (water used by soil vs. hydro, along with a conclusion). This can lead to a gallery walk or presentations, reinforcing communication skills.

9. **Discussion & Debrief:** Bring the class together to synthesize findings. Some points to draw out:

    - **Efficiency Results:** Likely, many will find the hydroponic uses less net water (since in soil, some water is lost as runoff or held in soil beyond what the plant uses). However, if a hydro system had issues (like water warmed and evaporated, or a lot of water added), discuss those anomalies.
    - **Reasons:** Soil's "leaky" nature vs hydro's closed loop. In soil, even without runoff, water can get bound in soil particles or evaporate from the soil surface. Hydro is more closed (especially if covered), so most water either goes into the plant or stays until it is evaporated – resulting in less outright waste.
    - **Trade-Offs:** Ask, "Does this mean hydroponics is always better?" Students should consider that hydroponics often requires electricity (for pumps and lights), careful nutrient management, and is typically used for small-scale or high-tech farms. Drip irrigation, although less efficient in this experiment, is still significantly more efficient than traditional flood irrigation and is practical over large areas with minimal technology. So each has a place.
    - **Sustainability Ideas:** What could a farmer do with runoff? (Capture and reuse it – some farms have return systems or use runoff to water other plants). What could an urban farmer do to improve hydroponic efficiency? (Use covers to reduce evaporation, use recirculating systems with pumps to grow more plants in one loop, etc.) Encourage creative thinking – this ties back to engineering and innovation, key parts of sustainable ag.
      Systems Thinking Reflection: Highlight how students basically mapped a mini water cycle. You can even draw a simple system diagram on the board: for soil pot – Water In -> [Plant/Soil System] -> water out (runoff, transpiration losses); for hydro – Water In -> [closed container + plant] -> losses (mainly transpiration). Show that in the big picture, transpiration from plants goes into the air (humidity), and runoff on a farm goes into groundwater or rivers. The activity's ledger concept can scale up to real irrigation scheduling and water budgeting in a region. This reinforces the **lesson A goals** about understanding different agri-systems across locations.

Differentiation & Scaffolding:

- For students who struggle with math, provide a worksheet or guide for summing and subtracting runoff, and have them work alongside a more confident peer or check their calculations as a class.
- For advanced learners, you could introduce the concept of **percent efficiency** (e.g., "What percent of the water you added to the soil was actually used by the plant?" and similarly for hydro). They could also consider water quality (did the pH change in hydro? Did soil leach nutrients out in runoff?) if you want to extend the inquiry.
- If time allows, consider incorporating a **career connection**, such as mentioning how irrigation engineers or urban hydroponic farm designers apply these same principles, or how water accounting is crucial in places like California for managing scarce water

resources. This can inspire students who enjoyed the activity to see real-world applications.

Safety Reminders (for teachers to enforce):

- Ensure that no student drinks or mishandles nutrient solutions or soil. Fertilizer solutions should be diluted and handled with gloves if they are concentrated.
- Monitor for mold or algae growth, especially if the classroom is warm and experiments run long. If any mold appears on the soil, have students reduce watering and, if necessary, end the trial if it becomes a hazard (although this is rare, but possible). Generally, good ventilation and regular monitoring are sufficient.
- If using grow lights to supplement natural light, secure them safely and turn them off when not in use to avoid any electrical hazards or overheating.

Cleanup and Conclusion:

- Have students responsibly dispose of the water (perhaps by watering school garden plants with the leftover water, rather than dumping it – a teachable moment in not wasting water!). Soil can be composted or saved, and plants could even be transplanted outdoors if viable. Hydro water can be poured out.
- Equipment such as jars and cups should be rinsed and stored properly. Emphasize cleaning up any spills.
- Collect worksheets or lab notebooks for assessment.

Grading Rubric

Use the following expectations rubric to evaluate short-response, short-essay, and design-based responses:

Criteria	Exemplary (4 pts)	Proficient (3 pts)	Developing (2 pts)	Beginning (1 pts)
Data Collection & Accuracy (Water measurements, plant data, L/kg calculations)	All measurements recorded accurately and completely; clear, organized data log; calculations correct and clearly shown.	Most measurements recorded; data log mostly complete; minor calculation errors.	Incomplete measurements or disorganized log; several calculation errors.	Minimal data recorded; calculations missing or incorrect.
Water-Use Efficiency Analysis (Comparison of drip vs hydro, factors discussed)	Insightful comparison with evidence; identifies multiple factors affecting efficiency; reasoning is clear and well supported.	Clear comparison with evidence; at least one factor affecting efficiency identified.	Limited comparison or unclear reasoning; minimal discussion of factors.	Little or no analysis of efficiency or factors.
Design Challenge – Compost Optimization (Diagram, interventions, and strategies)	The diagram is clear and labeled with intervention points; at least 3 thoughtful management strategies listed; each strategy clearly linked to gas pathways and outcomes.	Diagram present with labels; 3 strategies listed with general explanation of effects.	Diagram or strategies incomplete; connections to gas pathways unclear.	Diagram missing or very minimal; strategies missing or incorrect.
Systems Thinking & Environmental Connections (Shows understanding of cause/effect in agri-systems)	Demonstrates strong systems thinking; clearly connects management actions to environmental outcomes and sustainability.	Shows some systems thinking; general link between actions and outcomes.	Limited connection between actions and outcomes; reasoning vague.	Little or no evidence of systems thinking or environmental connections.
Communication & Presentation (Clarity, organization, and effort)	Work is neat, well-organized, and easy to follow; clear labels, units, and explanations; demonstrates high effort.	Work is organized and readable; most labels and units present; good effort.	Work is somewhat disorganized; some missing labels or unclear explanations.	Work is messy or incomplete; very hard to follow.

You can assign points or a grade holistically based on these. For example, a group that diligently collected data, showed clear understanding in answers, and maintained their systems well would receive full credit. Deduct if, say, data is incomplete or explanations are lacking. Include comments highlighting positives (e.g. “Great job linking the activity to real drip irrigation systems in your conclusion!”) and areas to improve (e.g. “Be careful with units – some of your entries didn’t note mL, which is important for clarity.”).

Notes: It’s expected that the hydroponic system often shows superior water efficiency, but if any group finds otherwise, it’s a great discussion opportunity. Perhaps their hydro plant grew more or drank more water, or an error occurred – treat it as a scientific investigation where outliers are analyzed, not just “wrong.” Encourage students’ curiosity to explain any unexpected results. This reinforces that in science, understanding “why” is as important as “what” the data show.

Finally, wrap up by tying this back into Module 6’s broader theme: **Agri-Systems Across the Urban–Rural Gradient**. Highlight that the skills and insights gained here (measuring resources, comparing systems, thinking of improvements) are exactly what sustainable food system designers and farmers do when deciding how to grow food in a city vs. on a farm. Students have experienced a bit of what it’s like to be both an **urban hydroponic grower** and a **rural farm manager** – and hopefully see how both can learn from each other in pursuit of conserving water and achieving sustainable agriculture.

Assessment Tip: Use the rubric to provide feedback. You might have students do a brief **lab report or presentation** as a summative assessment of this HOA, using their data and reflections. This can double as an assessment of their communication skills and ability to use evidence to support claims – aligning with NGSS science practices (arguing from evidence).