Fishing for Solutions: Trout Farming in the Slate Belt

The Lafayette Technology Clinic
2012 Final Report

Lafayette Technology Clinic 2011-2012

Executive Summary

Identification of Objectives

- Explore options for making fish farming in the Slate Belt more efficient, environmentally friendly, and cost-effective
- Develop prospective ideas which may be applied specifically to David and Rhonda Due's Country Springs Farm
- Pursue development of associated products that could be manufactured in the Slate Belt region to help boost the local economy
- Continue collaboration with the Dues to develop and implement ideas for improvement

Areas of Exploration

- *Potential for Stimulating Local Economy*- sell products to local restaurants consequently creating jobs and local partnerships
- *Use of Abandoned Buildings for Raising Fish*- provide an alternative space to outdoor ponds and make use of local underutilized resources
- *Aeration and Dissolved Oxygen Levels*- provide maximum aeration with minimum temperature increase
- *Temperature Control*- provide optimal temperature environment for trout at minimum cost possibly through shading and geothermal cooling
- *Predator Control*- explore the use of scare devices to deter predators
- *Making Use of Fish Waste*- develop efficient way of recycling fish waste
- *Solar Panels*- investigate the location, size, and cost of solar panels
- *Grants*- explore available grants that may be used to help manufacture and test solar lily pads
- *Market Research*- find ways to make locally grown trout more attractive to local restaurants and consumers

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I. Introduction
1.1 – Mission Statement

Research and propose an economically sustainable and environmentally conscious model to enhance fish farming operations in the Slate Belt region. Develop a solar lily pad through the use of Synectics and innovative design, while generating economic activity and fostering relationships with local restaurants and related communities.

I. Introduction
1.2 – Technology Clinic Overview

The Technology Clinic is an interdisciplinary course at Lafayette College in Easton, PA, which aims to provide students with the practical experience that many other classes lack. Since its inception in 1986, Tech Clinic has provided opportunities for small groups of highly motivated students – usually consisting of five or six members – to work closely with professors and other professional mentors to solve real-world problems. These students and professionals bring a variety of experiences, skills and perspectives that contribute to the authentically interdisciplinary nature of the course.

Lafayette Technology Clinic

I. Introduction
1.3 – Member Biographies

Stacey Goldberg is a senior pursuing a Bachelor's of Arts in Economics and Art (with a concentration in Art History). She is from Melville, New York and is the Managing Editor of *The Lafayette* student newspaper. She is involved in both the reporting and design aspects. Last year she studied abroad in Madrid, Spain and after college she will be working in corporate retail for Bed Bath and Beyond in Union, NJ.

Aaditya Khanal is a senior from Kathmandu, Nepal. He is pursuing Bachelor's of Science in Chemical Engineering . At the moment, Aaditya is also conducting honors research on Algae and biofuels. He will continue his studies after Lafayette in the field of Bioengineering at the University of Houston. He is an active member Minority Scientists and Engineers, AICHE and also a Calculus Calvary tutor. His interests include travelling , photography, soccer and computers.

Rachel LeWitt is a junior from Berywn, PA. She is currently pursuing a Bachelor's of Arts in Psychology and English. Rachel is involved in several aspects of life on Lafayette's campus including working as a Writing Associate, overseeing all things democratic as the President of College Democrats, and is an active member of Amnesty International and PAW: Promotion of Animal Welfare. Her interests include traveling, photography, learning, postmodernism, gastronomy, socializing and music.

Holden Ranz is a member of the class of 2012 at Lafayette College. He is pursuing a Bachelor's of Science in Chemical Engineering with a minor in Biotechnology/Bioengineering. He will continue his studies after graduation and earn a graduate degree in engineering, specializing in alternative energy or biofuels research at UC Davis. On campus, Holden conducts research with the Society of Environmental Engineers and Scientists in addition to tutoring organic chemistry. Outside of academia, he enjoys hiking with the Outdoors Society and plays a variety of racket sports, most notably table tennis.

I. Introduction
1.3 – Member Biographies

Garrett Rice is a senior from Mercersburg, PA. Pursuing a Bachelor of Arts in American Studies, he plans to attend law school beginning in the fall of 2012. At Lafayette, he is very involved as a varsity coxswain on the crew team and in the College Republicans. Garrett grew up on a large-scale goldfish hatchery that has been in his family for almost ninety years. In his free time, he enjoys spending time outdoors hunting, fishing, and boating. He is also an avid sports fan and is currently writing an honors thesis on the topic of the morality of sports violence in American football.

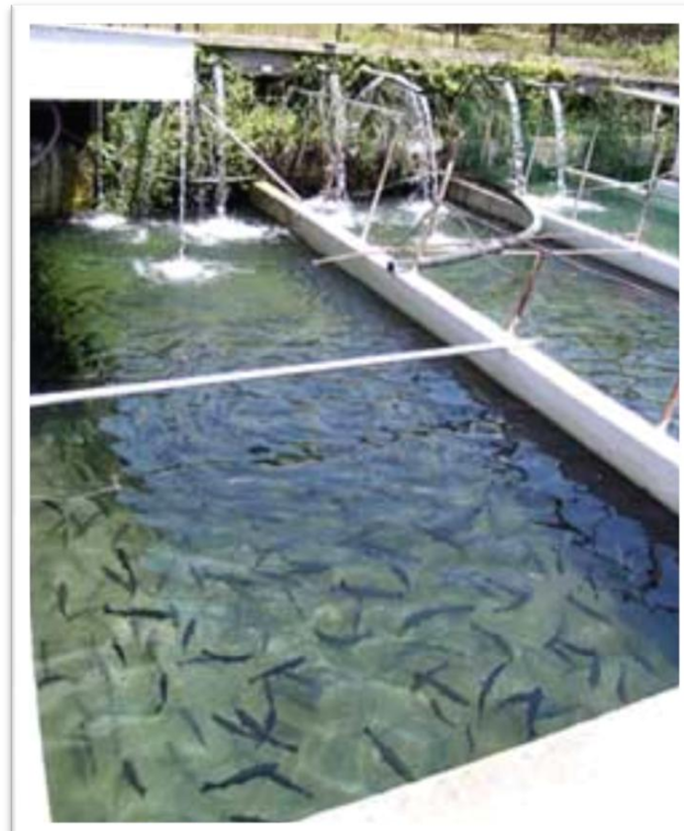
Yen Joe Tan is a sophomore from Penang, Malaysia. He is currently pursuing a Bachelor of Science in Geology and a Bachelor of Arts in Anthropology and Sociology. He is planning to do a study abroad in Tanzania in the fall of 2012. At Lafayette, he is a member of the Geology Club and the Badminton Club. In his free time, he enjoys playing basketball and pool.

Dan Bauer is a long-time resident of the Easton area who has lived in highland Peru, Ethiopia, and southern Mexico. He began his studies in engineering and, after completing a degree in Journalism and a stint in the Peace Corps, completed his PhD in Social Anthropology. He is the founding director of The Lafayette College Technology Clinic, which combines these interests.

Javad Tavakoli has lived in Easton since he joined Lafayette College in 1988. His BS, MS and PhD degrees are all in Chemical Engineering from Shiraz University in Iran, IIT in Chicago, and NJIT in Newark, NJ. He is a member of LV-Engineers Without Borders and helps the organization with its local and international projects

I. Introduction
I.4 – Background on Trout Farming

- Trout commonly raised in chutes
  - Simulates element of flowing water found in a natural environment
- Trout needs (compared to other fish)
  - Cool water
  - High oxygen content
- Risks
  - Predators
    - Birds (herons, ospreys)
    - Small mammals
  - Loss of fish due to extreme heat



Source: viva.org.uk/

I. Introduction
1.5 – History of Slate Belt

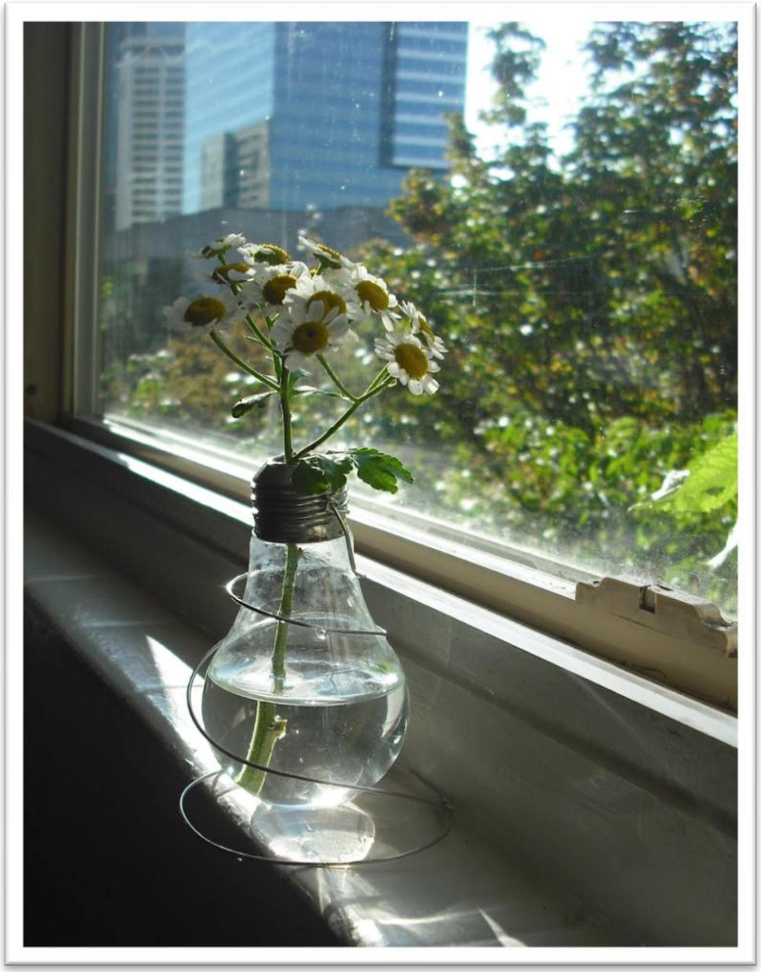
- The immigrants from Cornwall, UK, migrated to Bangor, East Bangor, and Pen Argyl after they were offered jobs in local quarries in late 1800s
- Later, immigrants from Roseto, Italy and other regions moved and settled in this area
- There is a major population of people of Italian, Welsh, and Cornwall origin
- By the mid-nineteenth century, slate roofing became popular in America and this area got its name "Slate Belt" because of its large deposits of slate
- As the mining industry declined, the textile business took over as the town's major employer

Source: maps.google.com

I. Introduction
1.6 – Approach Taken

- **<u>Synectics</u>** is the bringing together of seemingly unrelated ideas to create a new idea. It requires imagination and a problem that needs to be solved. It works by looking at comparable situations and potential solutions that lie within them. Often, solutions lie within nature and through analyzing how natural objects solve similar problems organically.

- By using Synectics, we can see how concepts within existing situations can translate to the problem at hand. It requires an application of logic and science to concepts in order to realize a solution.

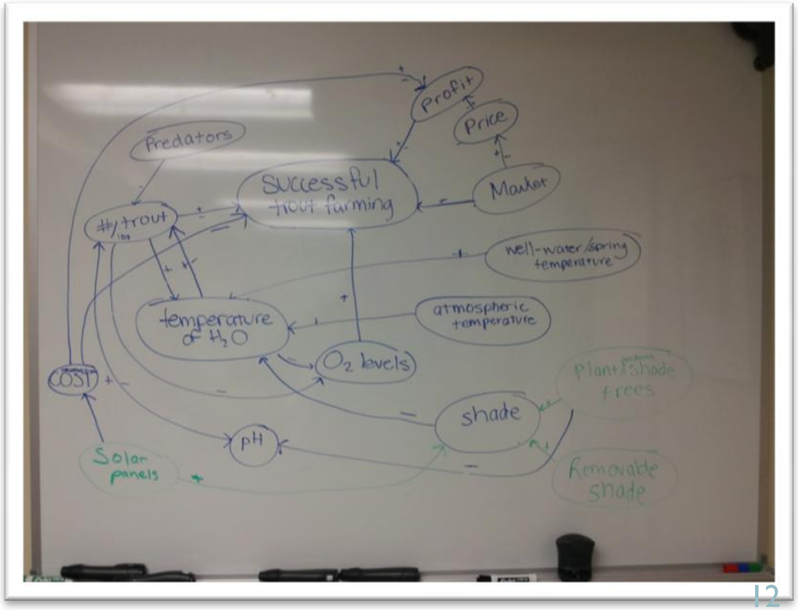


I. Introduction
1.7 – Tools Used

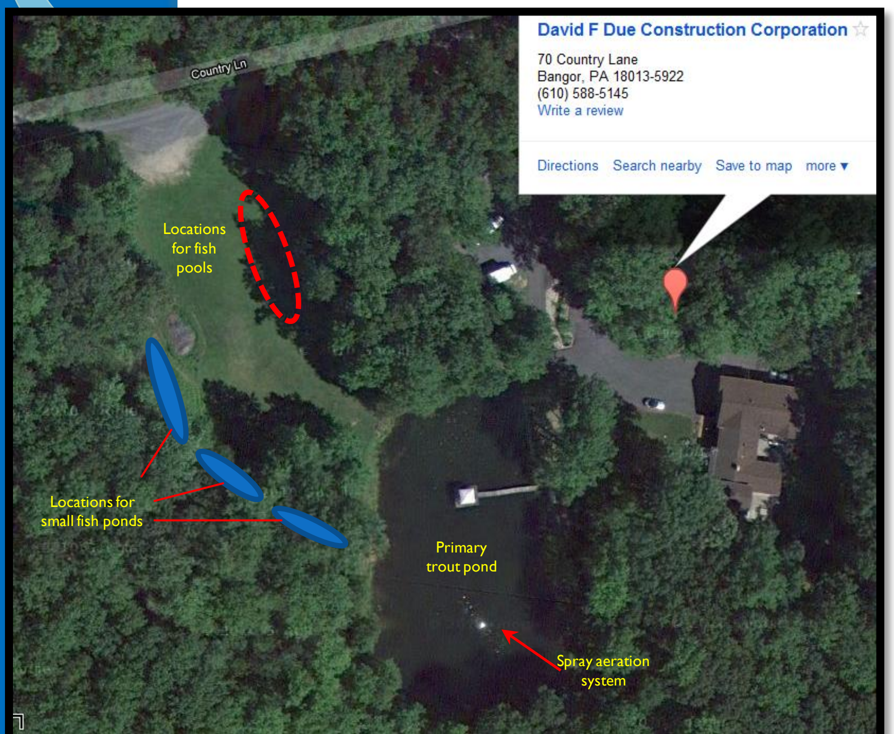
- **Wise Decider**
  - A program that weighs the values and alternatives of a problem and allows users to visually see the best solution based on these inputs

	Cooling effects	Cost	Physical impact on Fish	Additional effects (energy, aeration)	Maintenance	Impact of seasons	Aesthetic appeal
eothermal Cooling	Potentially high	High installation costs, pumping costs	None	Aeration if water is pumped back to the pond in a waterfall or through a fountain/sprayer	Minimal to none, if installed properly	Provides cooling in summer, warming in winter	Not a concern, underground
Man-Made Structure Shading	Could provide large shading area depending on set-up	Depending on size/materials, low or high	None	None, unless solar panels are used to provide shading	Minimal to none	Could collect snow in winter, structural hazard	Could be ugly, could be pretty --> addition to gazebo
pray Cooling	Only significant for hotter water	High power costs	Minimal, scares fish?	High	Minimal to none, if installed properly	cannot run below freezing	Fountains pleasant
quatic Plant Shading	Moderate to high	Very minimal cost to maintain living environment	Potentially high if they restrict ability of fish to swim	Potentially high	High if they take over the pond	Dies off in winter	High, flowers and lily pads, other aquatic life
ree Shading	Shade edges of pond	High initial cost, unless transplanting	None	None	Minimal to none	Loses leaves in fall/winter	High

- **Fuzzy Cognitive Maps**
  - Map out ideas to visually see how ideas relate to each other



2. Client's Vision
2.1 – Current Model and Project Motivation



- **<u>Background:</u>** David and Rhonda Due are raising fish in a pond that is about 60 years old. The gentleman who originally built it raised minnows which he sold for profit. The Dues purchased the pond 33 years ago and have been raising fish recreationally over the years. Their endeavors have become more serious in the past couple of years.

- **<u>The Challenge:</u>** In his current model, the biggest challenge is heat in the summer months (from the end of June to August). Around this time, the water temperatures spiked, dissolved oxygen levels plummeted, and the fish, which thrive in water around 60˚F, were unable to survive.

2. Client's Vision
2.2 – Job Growth and Economic Expansion

- Spur business in in the Slate Belt
  - Employing manufacturers to build floating lily pads
  - Selling fish waste as fertilizer
- Utilize abandoned warehouses for useful economic activity
- Create opportunities for other sectors of the local and regional community to benefit from their efforts
- Possibly open a route for other symbiotic businesses

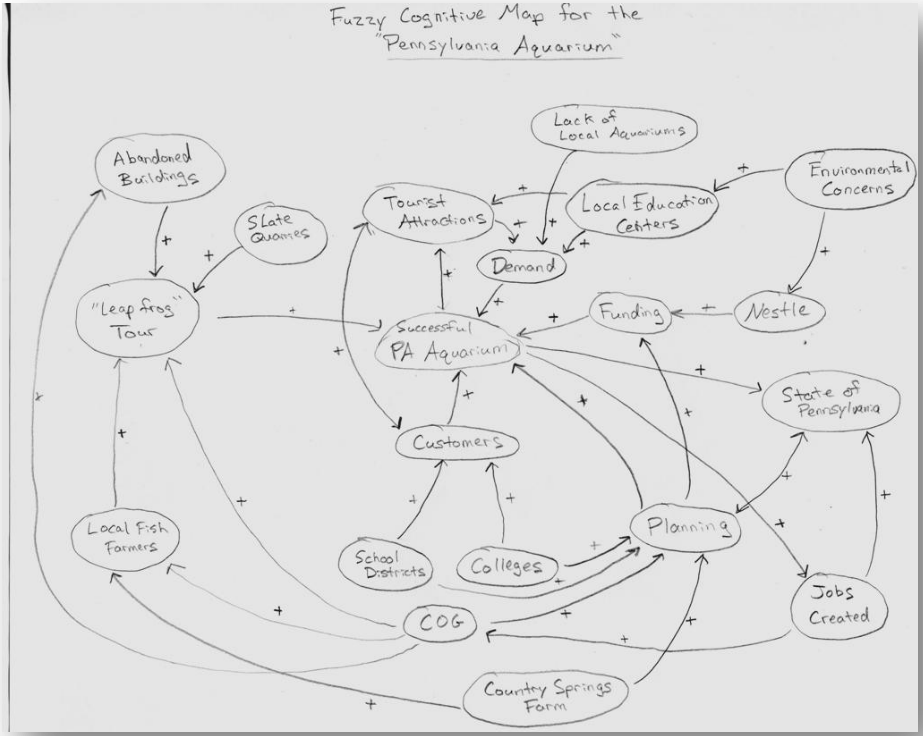
Buy Local

SPEND IT HERE • KEEP IT HERE

2. Client's Vision
2.3 – A Pennsylvania Aquarium

<u>Idea</u>: Building a large aquarium at the geographical center of the Slate Belt

- Closest aquariums to the Lehigh Valley are 2-5 hours away
  - Only other aquarium in Pennsylvania is in Pittsburgh
- "Leap Frog" tour would make use of abandoned factories and slate quarries in the Slate Belt and serve to educate people on local aquaculture



<u>Planning</u>: Include school districts, youth organizations, and local governments

- Local fish farms to be used as resources
- Possible funding by Nestles and grant money
- Involve the state of Pennsylvania in the planning process

2. Client's Vision
2.3 – A Pennsylvania Aquarium

- **<u>Tourism</u>**: The Slate Belt's geographic proximity to populated areas of New York City, Philadelphia, northern New Jersey, the Lehigh Valley, and the Poconos
  - Mutually benefit other tourist attractions in the region
    - Minor league baseball and hockey teams
    - Crayola factory
    - Pocono Mountains- Pocono raceway, skiing, water parks
    - Wineries and breweries
- **<u>Education</u>**: Combination of both the central aquarium and the "Leap Frog" tour to educate tour groups of families, school trips, youth organizations, etc.
  - Educate on both the natural local aquaculture and green fish farming
  - Include a nature conservatory and plans for local watersheds into the education aspect
- **<u>Effects on the Slate Belt</u>**:
  - Job creation
  - Spur business through increased exposure to other businesses in the region
  - Taking advantage of unused buildings and beautify parts of the area

2. Client's Vision
2.4 – Use of Abandoned Buildings

- We've explored the idea of using abandoned buildings and warehouses in Roseto and the surrounding area as suitable locations to farm fish indoors

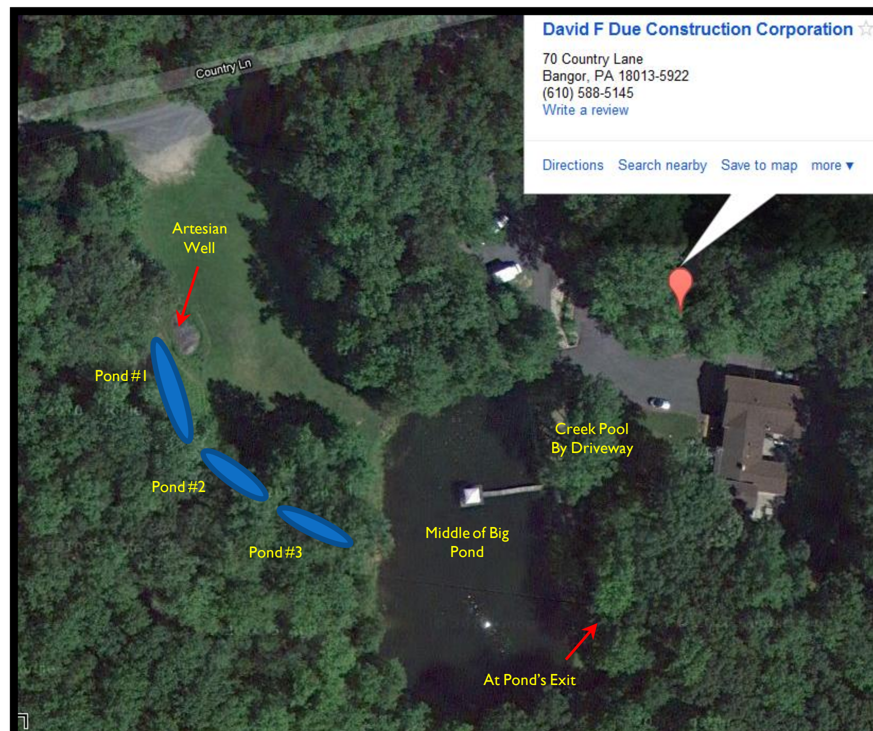
2. Client's Vision
2.4 – Use of Abandoned Buildings

- Underused local spaces could house fish farm tanks
- Several options exist including Recirculation Aquaculture Systems (RASs) and Do-it-yourself (DIY)
- Benefits
    - Secure space with access to public water, lighting, large space, and utilities
    - Protection from inclement weather and predators
    - Provide opportunities for employment
    - High productivity through controlled growth rates and short production cycles
        - Allows the farmer to stock the fish in higher densities relative to outdoor rearing due to the controlled atmosphere

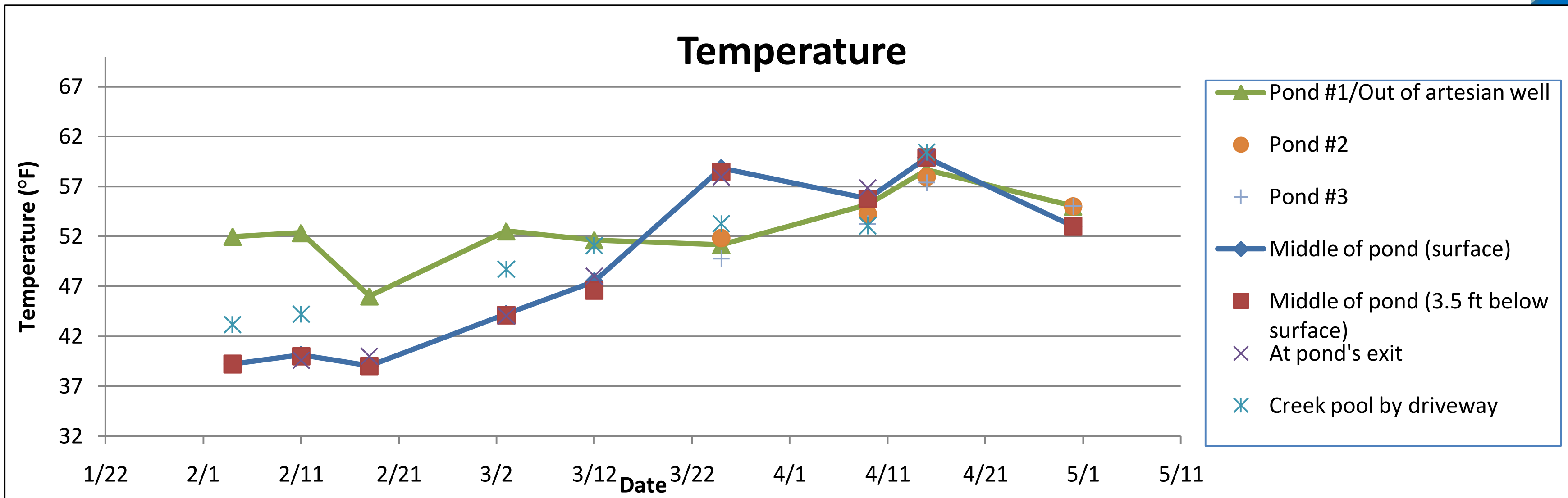
3. Technical Ideas
3.1 – Pond Records

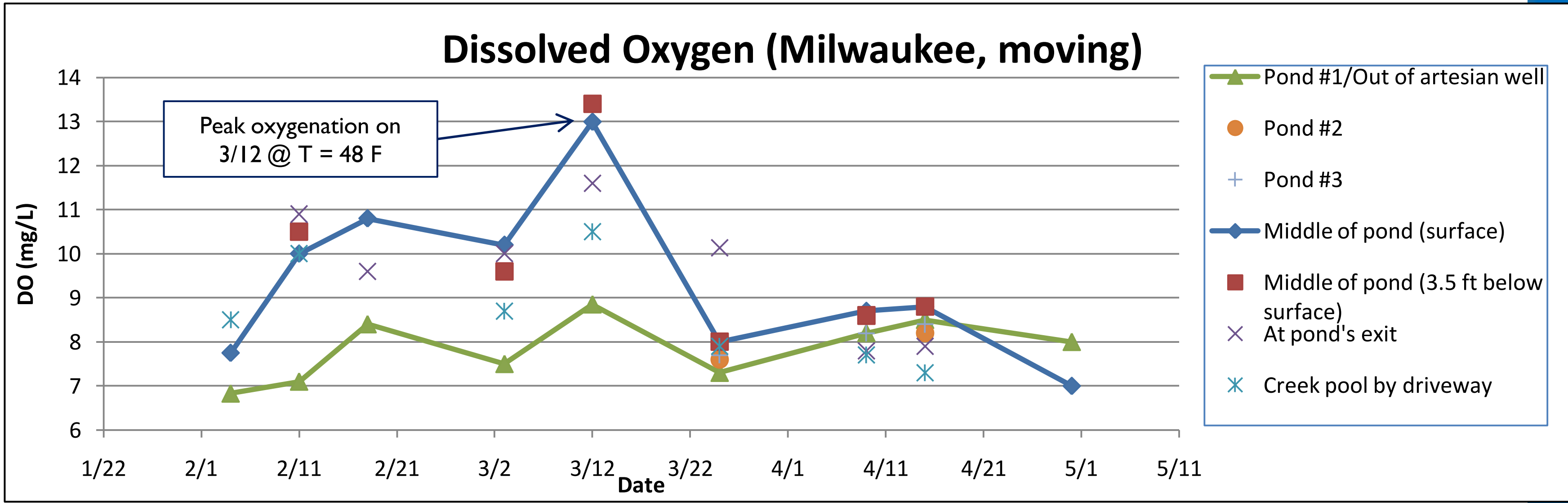
- Temperature, dissolved oxygen, and pH measurements were taken at various locations around the pond starting on February 4th, in attempt to characterize the chemistry of the pond with changing seasons
- Determine temperature effects on dissolved oxygen

- Locations
  - Pond #1/Out of artesian well
  - Pond #2
  - Pond #3
  - Middle of pond (surface)
  - Middle of pond (3.5 ft deep)
  - At pond's exit
  - Creek pool by driveway



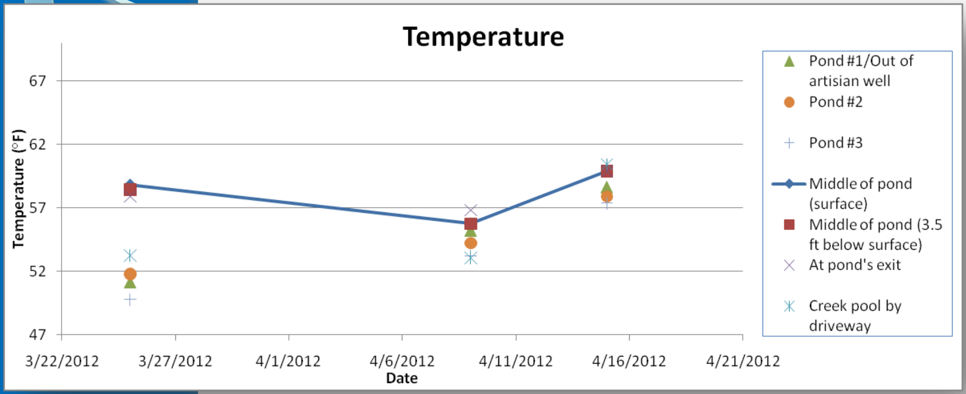
3. Technical Ideas
3.1 – Pond Records

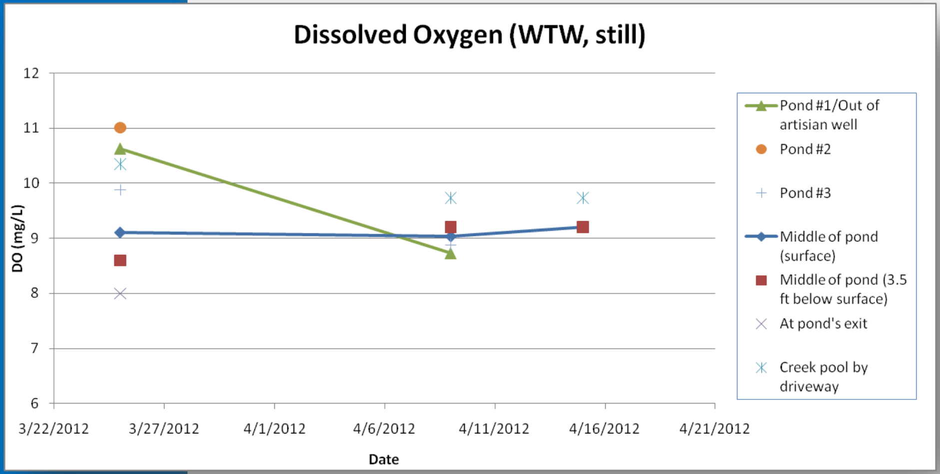


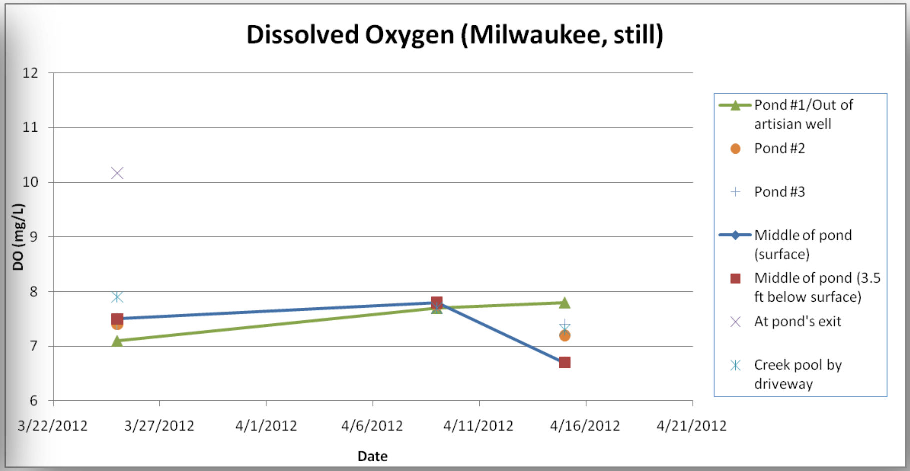


3. Technical Ideas
3.1 – Pond Records

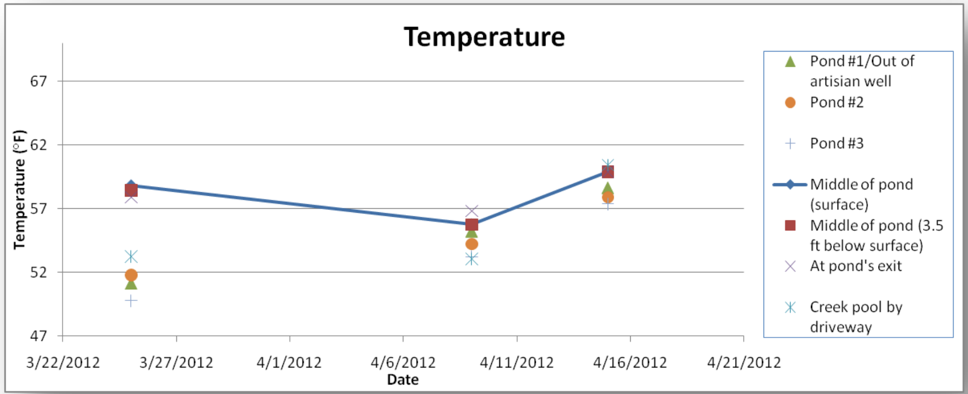
- DO measurements were taken with two different probes (WTW, Milwaukee)
- A difference in readings was observed between the two probes and whether or not it was held still or moving



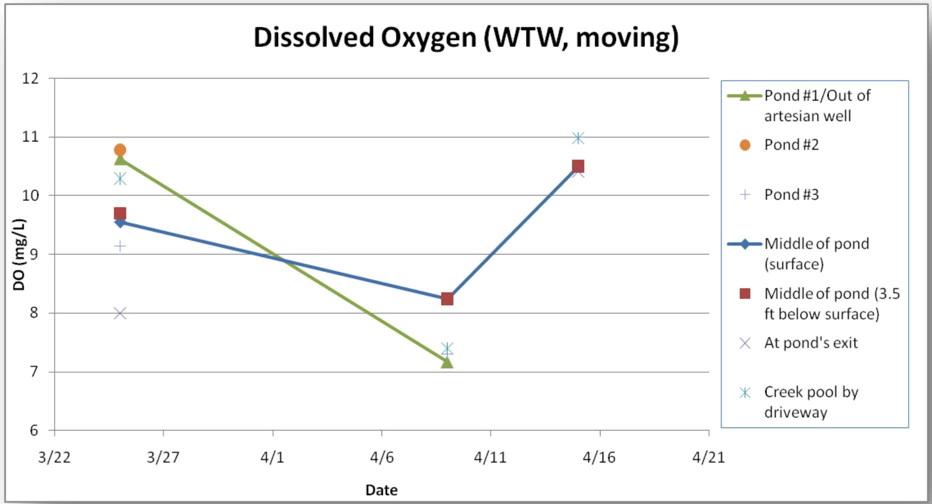


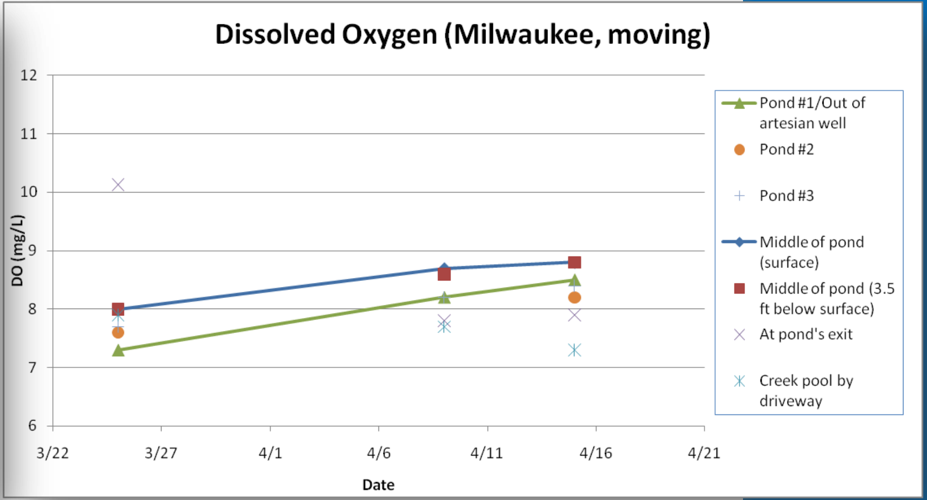


3. Technical Ideas
3.1 – Pond Records



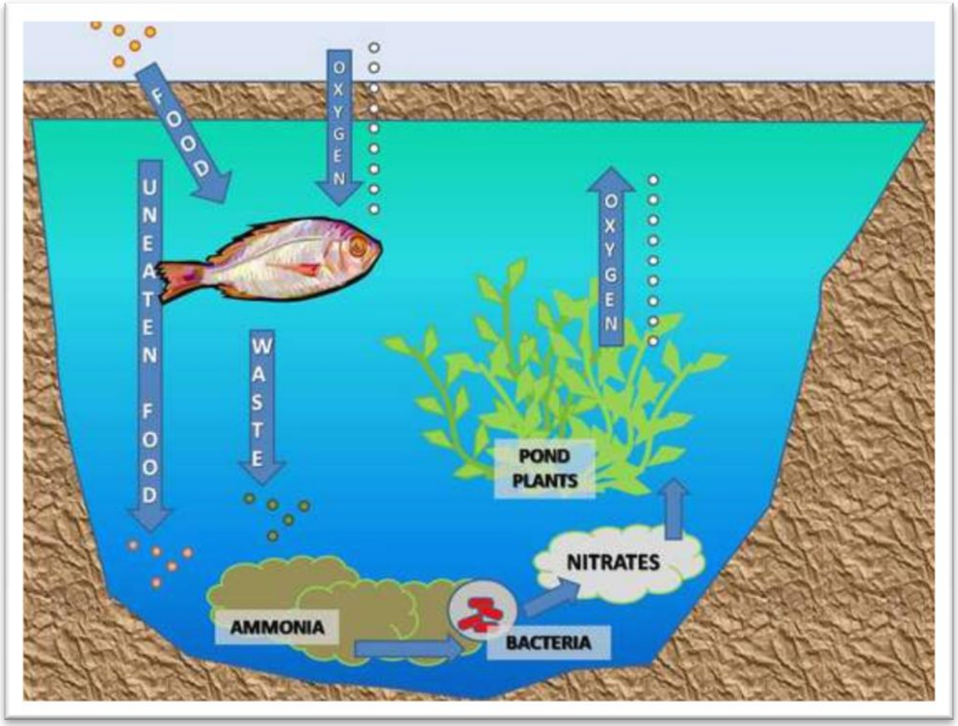
- Calibration issues and greater variability between measurements using the WTW lead us to believe the Milwaukee readings are most accurate





3. Technical Ideas
3.2 – Dissolved Oxygen

- Dissolved oxygen (DO) refers to oxygen gas that is dissolved in water. Fish use this oxygen, with the help of their gills, to perform respiration. Thus, continual supply of dissolved oxygen is required for the survival of all aquatic beings, including fish.



3. Technical Ideas
3.2 – Dissolved Oxygen

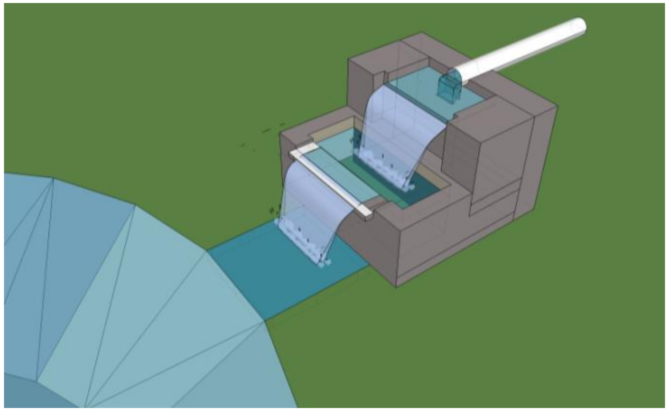
- There are three main sources of oxygen in the aquatic environment: direct diffusion, wind and wave action, and photosynthesis.
- Although photosynthesis is the largest contributor of dissolved oxygen, many aquatic plants are invasive and thus limit the movement of the fishes.
- Oxygen depletion occurs when the level of oxygen in water is below the minimum level required for the survival of the fishes. This level is roughly around 5 mg/L and mainly depends on the species of fish and is usually 7mg/L for salmonoids.
- Oxygen levels are directly related to the temperature of the pond as there is a negative correlation between temperature and oxygen levels.

3. Technical Ideas
3.2 – Dissolved Oxygen

- One of the main reasons for the fish-kill last summer was assumed to be low dissolved oxygen at higher temperatures. For example, water that is 90° F can only hold 7.4 mg/L DO at saturation, whereas water that is 45° F can hold 11.9 mg/L DO at saturation. This sets off a negative feedback loop as fish have higher oxygen demand at higher temperatures due to higher rates of metabolism.
- Thus additional aeration is required during the hot summer months to prevent any fish-kill in the future which was the main objective of this project.
- The pond already has a spray aerator which will be supplemented by other technologies in future. Several alternatives were researched and analyzed for this purpose.

3. Technical Ideas
3.2 – Dissolved Oxygen

- The first method that was found to be effective in other fish farms was artificial waterfalls which substantially increase the direct diffusion. We recommended this method during the mid-year presentation and our client has constructed a waterfall which should alleviate the problem during hot months.



Google Sketch-up of the proposed waterfall

Waterfall constructed based on the recommendation of the Tech Clinic

3. Technical Ideas
3.2 – Dissolved Oxygen

- Other potential methods:
  - Use of chilled air from radiator/air conditioner
  - Electrolyze the water using a low voltage electrolysis of water
  - Use the solar lily pads to generate electricity which would be used to pump air into the pond
- Proposed methods for the future:
  - Use window screens to increase the agitation thereby increasing the oxygen levels in the pond
  - Bottom diffusing aerators

Bottom diffusing aerators


Window screens to increase the agitation thereby increasing DO

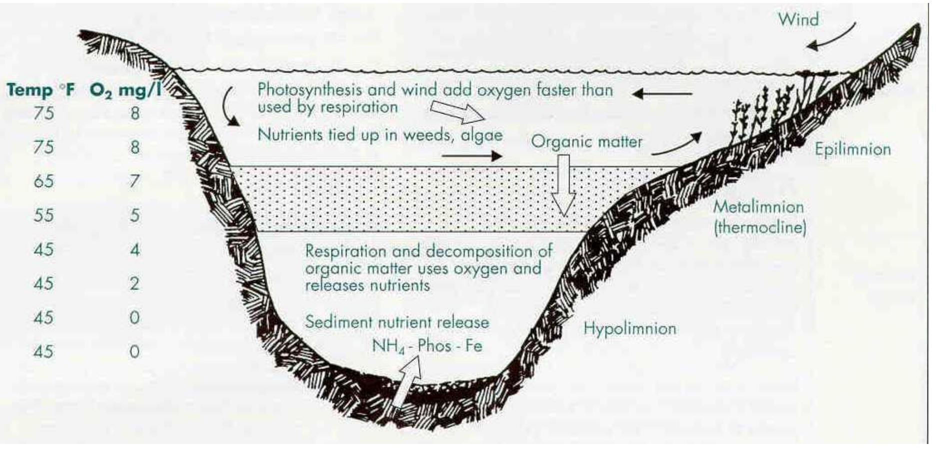
3. Technical Ideas
3.3 – Biological Oxygen Demand

- Oxygen requirements of microorganisms and macroinvertebrates removes dissolved oxygen available for trout in the pond
- Testing to be done:
  - Measure using 5-day EPA method
  - Send to lab to determine BOD and other important variables affecting the pond chemistry (TDS, ammonia, etc.)

3. Technical Ideas
3.4 – Temperature

- Rainbow trout is a cold-water fish:
  - Optimum temperature for metabolism: 65 °F
  - High mortality rates occur between: 75 – 80 °F
  - Show reduced feeding, hence lower growth rates above 68 °F

Higher water temperature = lower dissolved oxygen levels!



Source: dnr.wi.gov/

3. Technical Ideas
3.4 – Temperature

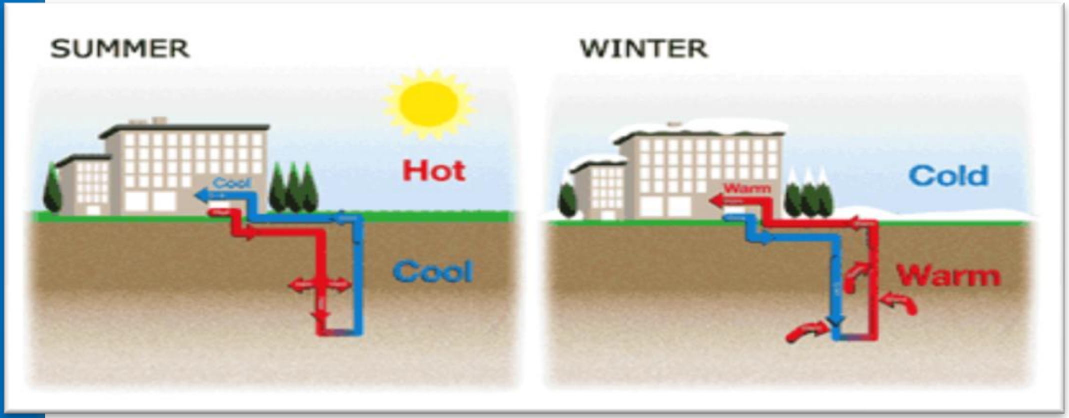
- Potential temperature control methods:
  - Shading
    - Solar panels, man-made structures
      - Incur a more significant cost
    - Natural - trees, aquatic plants
      - Issue of introducing invasive species
  - Spray cooling
    - Done from the edge
      - prevent system from heating up the pond
    - More effective for cooling much higher temperature

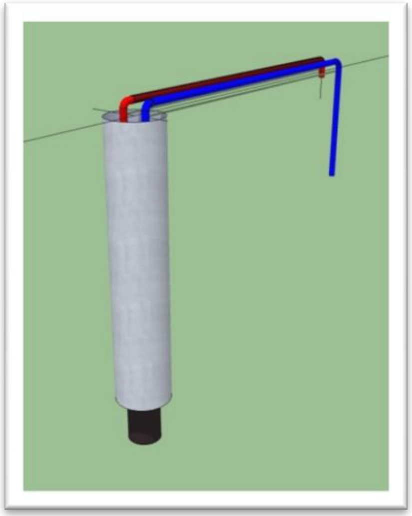
Source: aquaticpictures.com

Source: sugartech.co.za/spraypond/spraypond.jpg

3. Technical Ideas
3.4 – Temperature

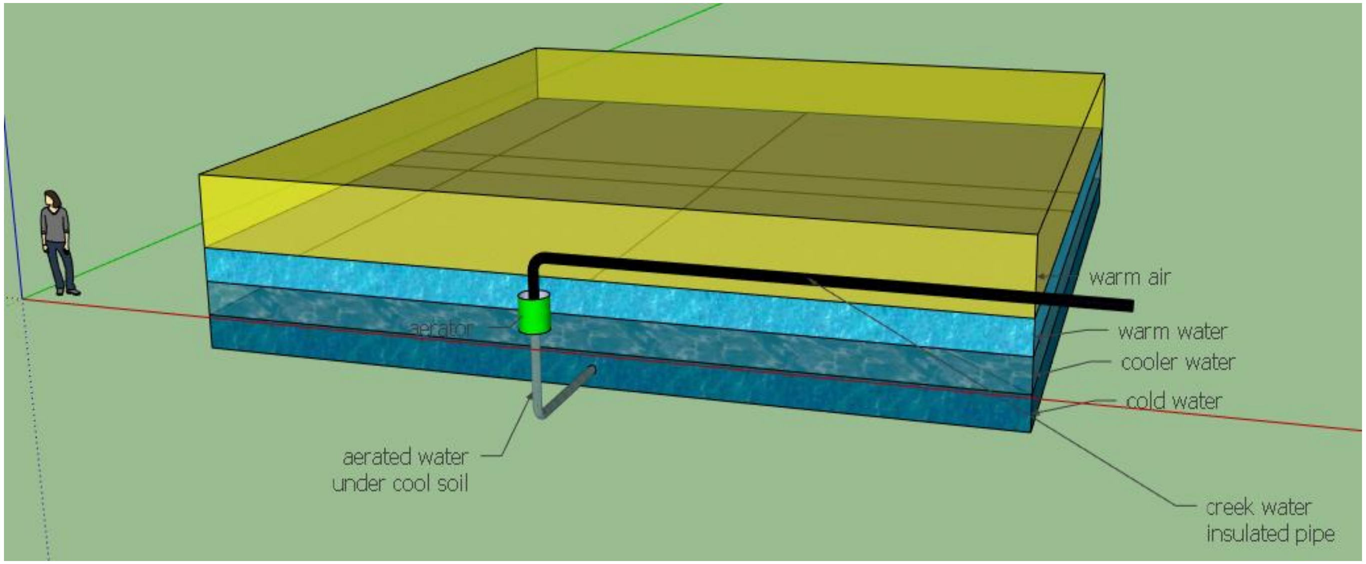
- Geothermal
  - At a depth of below four feet, ground temperature stays relatively constant at 50-55 °F year round
  - Pond water will be circulated underground to cool it before being pumped back into the pond
  - Requires additional pumping thus potentially costly
  - Pump to upstream ponds for additional cooling and aeration





Google SketchUp
geothermal cooling model

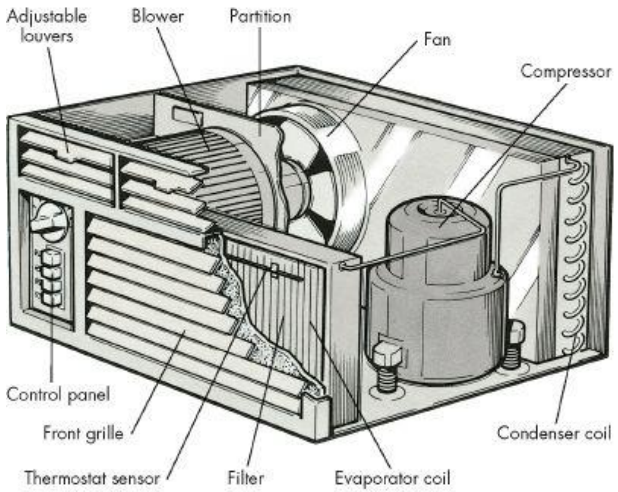
3. Technical Ideas
3.4 – Temperature



- Maintaining stratification of pond
  - Pumping cooled, aerated air into the bottom later of the pond to prevent disturbing the water column
  - More energy efficient as there will not be a need to cool down the whole amount of water within the pond

3. Technical Ideas
3.4 – Temperature

- Aerating the pond with cool air
  - Conventional aeration methods raise air temperature
  - Air-conditioning
  - Water-cooled radiator



Source: howstuffworks.com

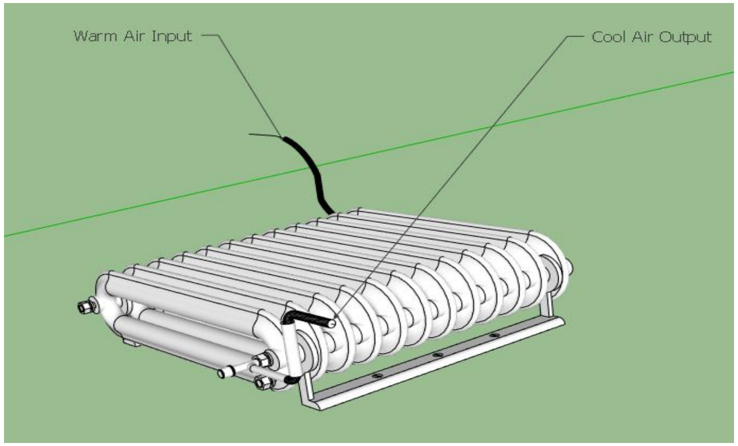


Figure: Radiator

3. Technical Ideas
3.4 – Temperature

Air Conditioner

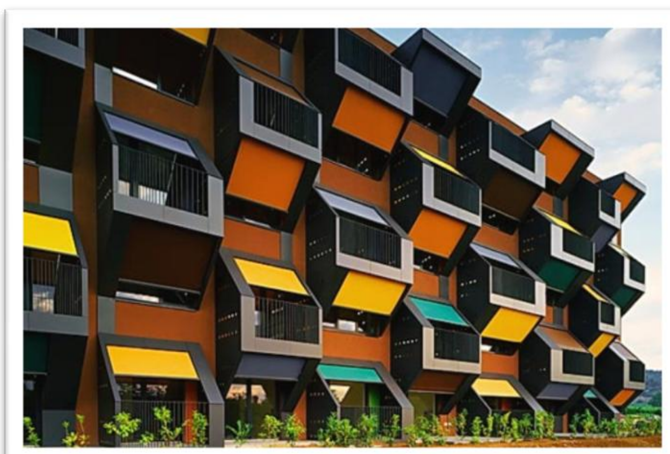
- Advantages
  - Works even during the hottest seasons
- Drawbacks
  - Uses fossil fuels
  - Operating cost

Water Cooled Radiator

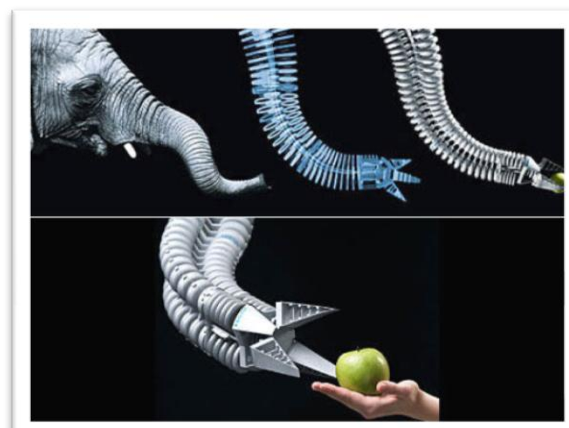
- Placing a radiator in a nearby stream and using the cooler water to cool down the air before pumping into the pond
- Advantages
  - Environmentally clean
  - No fossil fuels
- Drawbacks
  - Not as effective during time of highest demand

3. Technical Ideas
3.5 – Solar Lily Pads

- Biomimicry
  - The examination of nature and its underlying systems in order to influence the design of sustainable solutions to human problems
  - An actual lily pad converts solar energy to chemical energy through photosynthesis, allowing for sustainable growth of the plant while shading/cooling the water below it
    - Using this concept, we are able to mimic nature's solution in our design



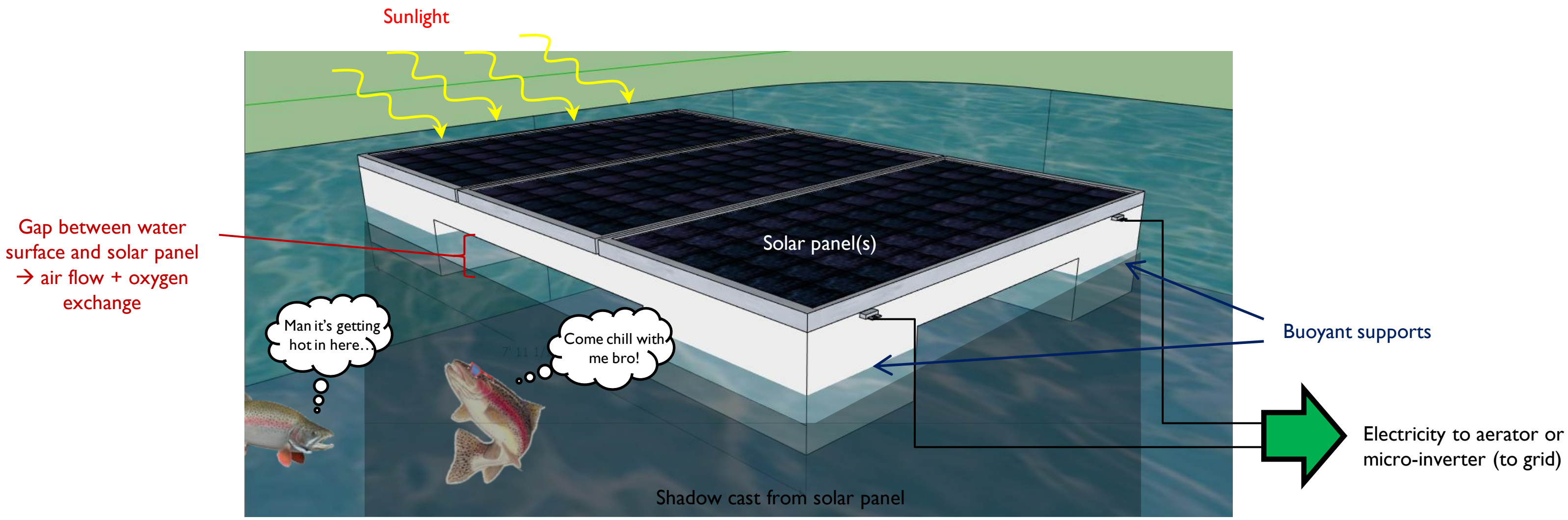
Housing complex in Slovenia that is a series of honeycomb modular apartments
Source: inhabitat.com



A robotic arm like that of an elephant trunk
Source: webecoist.momtastic.com

3. Technical Ideas
3.5 – Solar Lily Pads

- Thought process
  - Renewable energy → solar panels
  - + Temperature control → shading
  - + Oxygen levels → aerators
  - + Fish predator deterrent → moving device
  - = Solar lily pad



Solar lily pad concept drawing

3. Technical Ideas
3.5 – Solar Lily Pads

- Renewable energy
  - The solar lily pads have been designed to include a solar panel mounted on a raft-like support structure
  - The solar energy captured will be converted into electricity to help offset fossil fuel consumption of aerators
    - Electricity used immediately to power aeration → stand alone product
    - Electricity sent back into the grid → government support

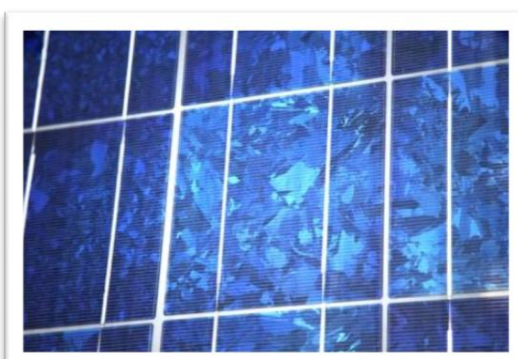
- Shading
  - In their natural habitat, fish take advantage of lily pads for their shading benefits, resulting in areas of lower temperature
  - The solar lily pads will provide shade similar to that of an actual lily pad by blocking the surface of the pond from the sun

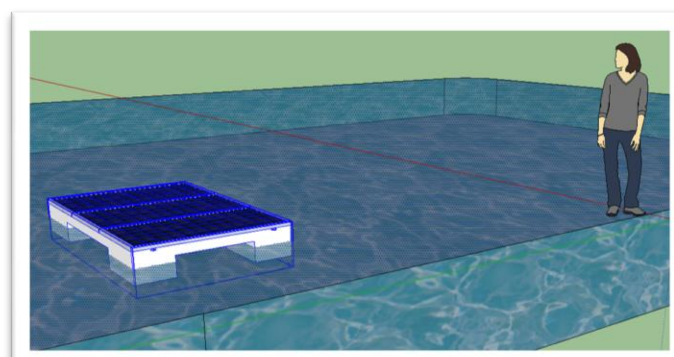
3. Technical Ideas
3.5 – Solar Lily Pads

- Oxygen
  - The solar lily pads will deliver electricity for the various aeration methods (top-bubbling aerators, bottom-diffusing aerators, electrolyzer)
  - They will incorporate buoyant supports at each of the corners in such a way that minimizes the amount of mass-transfer area removed at the air-water interface
    - Maintains oxygen exchange with atmosphere
- Fish predator deterrent
  - The pond coverage and movement provided by the lily pads will ideally deter predators such as herons, ospreys, raccoons

3. Technical Ideas
3.5 – Solar Lily Pads

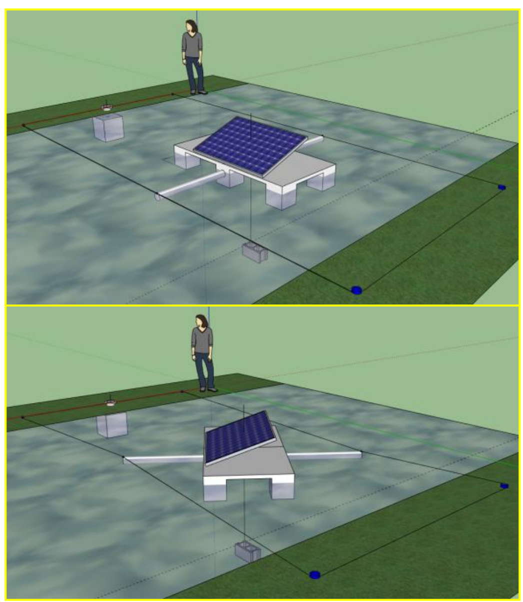
- Design and Construction
  - Polycrystalline silicon solar PV panels, approximately 4' x 8'
  - Rigid frame required to support the panels (metal, wood, plastic, trex), bumper on outer edge (rubber, plastic)
  - Buoyant supports located at each corner
    - Polyisocyanurate foam
    - Additional supports may be added under the main body of the panel to provide further stability



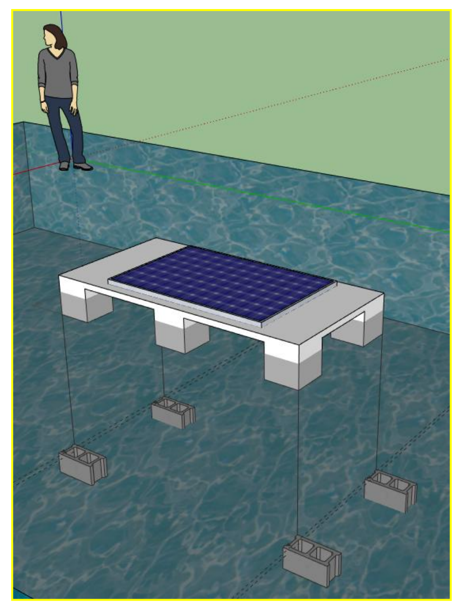


3. Technical Ideas
3.5 – Solar Lily Pads

- Additional panel ideas
  - Mount to allow for panel tilt
  - Motor with rigging/pulley system to rotate and shift azimuth of the solar panel throughout the day → increase efficiency
  - Strategic anchor location to control mobility and stability



Rotational-panel → Top = 12pm, Bottom = 3pm



Anchored panel → four cinderblock anchors

3. Technical Ideas
3.5 – Solar Lily Pads

- Stand alone product
  - Benefits
    - Appeal of single unit, easy to install aerator system
    - Good for locations away from utility
    - Easily marketable
  - Disadvantages
    - Energy supply infrequency → no electricity generation when overcast → lack of aeration
- Grid-connected solar power
  - Benefits
    - Can profit off excess electricity generation
    - Constant supply of electricity from grid for aeration
  - Disadvantages
    - More involved/expensive installation process → solar panel hook up to micro grid tie power inverter, which plugs directly into utility and reverses flow of electricity when harvesting energy
    - Difficult to install if utility not available in desired location
- Additional benefits
  - Potential patent for stand alone product
  - Bring jobs/industry to the Slate Belt
  - Uses throughout the aquaculture industry

3. Technical Ideas
3.6 – Predator Control

- Visual scare devices
  - Scarecrows
  - Lights
  - Reflectors or Mirrors
  - Predator models

Predator model of an alligator

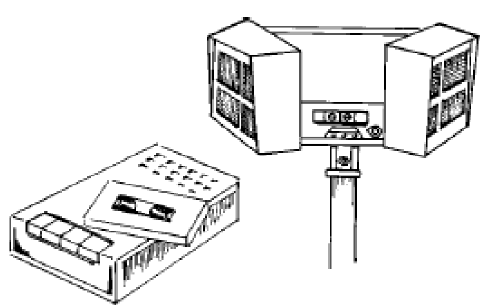
- This method is effective for a short duration.
- After a week or so birds get used to the scare devices.
- One method is to change the location frequently.

Electronic owl with motion sensor

Night light that scares away predators

3. Technical Ideas
3.6 – Predator Control

- Possible Methods:
  - Barrier
    - Useful against animals like raccoon, feral cats etc.
    - Not aesthetically pleasing and not effective against aerial predators.
  - Noise
    - Distress calls and pyrotechnic devices
      - Not practical around residential areas.
      - Predators get used to it after some time.



Recorded "gunshots" from speakers

3. Technical Ideas
3.6 – Predator Control

- Possible applicable methods
  - Motion activated sprinkler
    - Has shown efficacy in other fish farming
    - Covers an area of about 1000 sq. feet and runs on 9 volt battery.
    - Price: $44.39 on Amazon
    - Two "Scarecrow" sprinklers are sufficient to cover Mr. Due's pond.
  - Ultrasonic Repeller:
    - Could be useful against amphibious animals like raccoons.
    - Price: $33.00 on Amazon
    - Covers an area of 4000 sq. feet, so one should be sufficient.

3. Technical Ideas
3.7 – Dealing with Fish Waste

- Idea of selling fish waste in local markets to be used as organic fertilizer
- Two things required to implement this plan:
  - Market must be available in local economy
  - Profit from selling waste must be greater than cost of equipment, maintenance, and operation
- FIAP Parabolic Screen Filter and pump would need to be purchased
- Fish waste currently being sold as organic fertilizer by large companies like Organica

The FIAP Parabolic Screen Filter

4. Grants
4.1– Benefits

- Applying for external funding through grants allows the Dues to combine their vision of a sustainable fish farm with a marketable idea: the solar lily pad
- Grants emphasize innovation, economic impact, technological advancement and the possibility for job growth
- Several grants are geared specifically to Pennsylvania, and could provide the start-up money necessary to begin manufacturing the solar lily pads

4. Grants
4.2 – Grants Explored

- Ben Franklin Technology Partner's Challenge Grant and Alternative Energy Development Program
- Rural Business Opportunity Grants (RBOG)
- Pollution Prevention Assistance Account
- First Industries Agriculture Program
- Industry/University Cooperative Research Centers Program (I/UCRC)
- Innovation Corps Program (I-Corps)
- 2012 PA Conservation Innovation Grant
- Industrial Sites Reuse Program
- Opportunity Grant Program
- Infrastructure Development Program
- Solar Energy Program

5. Market Research

- According to David Due, there are not many other fish farmers in the Roseto region. There are two hatcheries, Greenwalk and Cherry Valley that also grow and sell fish.
- After speaking with restaurant owners in the local area, the potential of serving locally grown fish from a sustainable farm was very positive.
- Some restaurants suggested using pictures of the farm on their menu to show just how local and fresh the fish are.

5. Market Research
5.1 – US Trends

- A **locavore** has been defined as "a person interested in eating foods that are locally produced, not moved long distances to market." This term goes hand-in-hand with foods that are also sustainable and eco-conscious.
- This movement is a growing trend and restaurants in the Lehigh Valley have responded positively to the movement.
- Restaurant sales in the United States were estimated to be $604 billion in 2011.
- The number one trend in entrees in restaurants in the United States in 2011 is locally sourced meats and seafood. The second most popular trend is sustainable seafood.

6. Appendices

- Extended Pond Records

Pond Records	Location	Dates							
		2/4/2012	2/11/2012	2/18/2012	3/3/2012	3/12/2012	3/25/2012	4/9/2012	4/15/2012
pH	Pond #1/Out of artesian well	7	6.38		7	7	7.55	7.17	8.88
	Pond #2						7.38		8.67
	Pond #3						7.43	7.3	8.63
	Middle of pond (surface)	7.86	7.59		8.43	7.8	8.17	8.24	8.75
	Middle of pond (3.5 ft below surface)	7.86	7.59		8.43	7.8	7.75	8.24	
	At pond's exit		7.94		7.32	7.84	7.69		8.54
	Creek pool by driveway	7.2	7.67		7.21	7.66	7.71	7.4	7.4
Conductivity (uS/cm)	Middle of pond (surface)					84.9			
	Middle of pond (3.5 ft below surface)					86.5			
	Straight out of artesian well					86.3			
	At pond's exit					80.4			
	Creek pool by driveway					81.8			
Hardness (mg/L)	Middle of pond (surface)	140	120	160					
	Middle of pond (3.5 ft below surface)								
	Straight out of artesian well		140						
	At pond's exit		120						
	Creek pool by driveway		120						

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- Dave Rowan- Crayola, Product Development
- Frank Russo- Tellus Underground Technology
- Nancy Waters- Lafayette College Biology Department
- Stephen Willey- Willey Aquafarm, former owner

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