Abstract

One of the major water pollutants caused by human includes land erosion (sedimentation of soil and silt), and surface runoff that arises from urban development. These pollutants provide nutrients that cause excessive growth of algae and other aquatic plants which contribute to nutrient loadings and may deplete the amount of dissolved oxygen necessary for the fish to survive. Additionally, water with excessive levels of sediment may cause encroachment of vegetation into a channel that disrupts life cycles of various aquatic organisms and affect the marine food web.

The goal of this project is to build an unmanned underwater sensor that will be used for water sampling in order to monitor pollution. The ECO-SUB device will house a set of sensors that will record time and location when critical levels of nitrogen, oxygen and phosphorus are reached and when drastic changes of pH and temperature occurs. Water samples from the Ballona wetlands and the Whittier Narrows Lake will be tested for these pollutants, and their data will be recorded. Ultimately, our objective is to evaluate water quality from Tijuana River to the San Diego estuaries and to help identify the potential source of pollution.

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Introduction

During the past 100 years, we have been intervening in the earth's current water cycle in three major ways. First, we withdraw large quantities of fresh water from streams, lakes, and underground sources. Second, we clear vegetation from land for agriculture, mining, road and building construction, and other activities and sometimes cover the land with buildings, concrete, or asphalt. This increases runoff, reduces infiltration that recharges groundwater supplies, increases the risk of flooding, and accelerates soil erosion and landslides. We also increase flooding by destroying wetlands, which act like "sponges" to absorb and hold overflows of water. Third, we add nutrients (such as phosphates and nitrate found in fertilizers) and other pollutants to water. This overload of plant nutrients can change or impair natural ecological processes that purify water.

Water, a precious natural resource, is essential for multiplicity of purposes. Water constitutes the major bulk (79%-90%) of all living cells. Water is an essential, life-supporting factor in every cell (microcosm), individual organism, ecosystem, and cosmos. Freshwater is utilized in drinking, several domestic ad household purposes, industrial cooling, power generation, agricultural irrigation, and waste disposal. Since time immemorial, water bodies (river, lakes, and oceans) have been the cheapest route of transportation. Today, in almost all spheres of human activity, a far larger amount of waster is drawn out than what is actually required. Due to careless and excessive uses, a major bulk of water is drained out in an impure state as waste. The rapid rise in demand for freshwater is a manifestation of an equally rapid growth in the number of consumers and the growing population.

The purpose of this project is to build an unmanned underwater sensor that will be used in assessing water quality and to monitor pollution. The device will house a set of sensors which includes an ion selective probe (nitrate), dissolved oxygen, pH and a temperature probe. The sensors are connected to a Vernier Datalogger which will record various data at a programmed time interval.

Eutrophication

Eutrophication is a kind of nutrient-enrichment process of any aquatic body, which results in an excessive growth of phytoplankton. This undesirable overgrowth of aquatic plants and their subsequent death form a greenish slime layer over the surface of the water body. The slime layer reduces light penetration and restricts reoxygenation of water through air currents. The death and decay of aquatic plants produces a foul smell and makes the water more turbid (Beeby 1995; Rao 1998).

Eutrophication, or the promotion of the growth of plants, animals, and micoorganism in lakes and rivers, has been a very slow, natural process. If this is allowed to occur uninterrupted it results in an excessive deficiency of oxygen in the water. Thus organisms that thrive under anaerobic conditions are favored more and more at the expense of aerobic organisms (Mengel & Kirkby 1996). In surface waters, phosphorus concentrations exceeding 0.05 mg/L^{-1} may cause eutrophic conditions (Hinesly & Jones 1990). Eutrophication of drainage ditches by overfertilization with nitrogen and phosphorus causes a shift mainly from submerged aquatic vegetation to a dominance of floating duckweeds. This results in anoxic conditions, loss of biodiversity, and hampering of the agricultural functions of such ditches (Janse & Puijenbroek 1998). The change in eutrophic conditions is reflected in the occurrence, pattern of distribution, and diversity of the biotic community (Tiwari 1998).

Many natural water bodies are descried as oligotrophic, for they have clear-water ecosystems in which primary and secondary productivities are limited by a shortage of major nutrients (Beeby 1995). These oligotrophic water bodies, if brought under natural succession, require thousands of years to become eutrophic. The enrichment of aquatic ecosystems through the discharge of human wastes from settlements and excessive fertilizers from agricultural lands brings down the water bodies undesirably increased rate of eutrophication.

Eutrophication is one of the serious kinds of water pollution directly affecting the fauna due to the loss of dissolved oxygen. It leads to an early and relatively faster mortality rate of fish and thus spoils the desired water quantities of ponds and lakes. Fishing and navigation in eutrophic water become difficult due to enmeshed and heavy growth of plants. Hydroelectric generation from such water storage is adversely affected as nutrient rich water acts chemically upon the turbines. At the end of an algal bloom, the decomposing debris also spoils the desired water characteristics and may result in the growth of disease-causing bacteria. Uncontrolled eutrophication leads to a rapid upwelling of a water body. Silting reduces the limited storage and water-recharging capacity of smaller freshwater bodies. Small lakes and many ponds steadily lose their aquatic entity and become permanently terrestrial in nature. Eutrophication leads to significant changes in water quality. It lowers the value of surface waters for the industrial and recreational uses. Overpopulation of algae makes water unfit for swimming. Algae growing in the long strands often twine around boat propelled and make boating difficult. Eutrophic waters tend to be scummy, cloudy, or even soupy green. The rapidly growing aquatic plants may wash onto the shore in storms or high winds. Where these plants die, decay produces a bad smell all around such water bodies (Penelope & Charles 1992).

Parameters to measure:

Nitrate

Nitrogen is the atmosphere's most abundant element, with nitrogen gas (N_2) making up 78% of the volume of the troposphere. The N2 in the atmosphere is a stable molecule that does not readily react with other elements, so it cannot be absorbed and used directly as a nutrient by multicellular plants or animals.

Humans intervene in the nitrogen cycle in several ways. First, we add large amounts of nitric oxide (NO) into the atmosphere when N_2 and O2 combine as we burn any fuel at high temperatures. In the atmosphere, this gas can be converted to nitrogen dioxide gas (NO_2) and nitric acid (HNO_3), which can return to the earth's surface as damaging acid deposition, commonly called acid rain.

Second, we add nitrous oxide (N_2O) to all atmospheres through the action of anaerobic bacteria on livestock wastes and commercial inorganic fertilizers applied to the soil. This gas can warm the atmosphere and deplete ozone in the stratosphere.

Third, nitrate (NO_3-) in inorganic fertilizers can leach through the soil and contaminate groundwater. This contaminated groundwater is harmful to drink, especially for infants and small children. Nitrogen and phosphorus are essential elements required by plants and animals for maintaining their growth and metabolism. Small amounts of nitrates and phosphates occur in all aquatic ecosystems and maintain a balanced biological growth in such ecosystems. In wastewater, these nutrients are abundant as phosphates, nitrate, and ammonia or combine organic nitrogen. These compounds enter the water bodies directly from the fertilizer manufacturing and processing units or from the agro ecosystems having excessive applications. In their model, Welch and Crooke (1987) predicted the decline in phosphorus loading by diverting effluents away from Lake Washington, which became eutrophic as the city of Seattle expanded.

Fourth, we release large quantities of nitrogen stored in soils and plants as gaseous compounds into the troposphere through destruction of forests, grasslands, and wetlands.

Fifth, we upset aquatic ecosystems by adding excess nitrates in agricultural runoff and discharges from municipal sewage systems.

Sixth, we remove nitrogen from topsoil when we harvest nitrogen-rich crops, irrigate crops, and burn or clear grasslands and forest before planting crops.

Since 1950, human activities have more than doubled the annual release of nitrogen from the terrestrial portion of the earth into the rest of the environment. This excessive input of nitrogen into the air and waster presents a serious local, regional, and global environmental problem that has attracted relatively little attention compared to global environmental problems such as global warming and depletion of ozone in the stratosphere. Princeton University physicist Robert Socolow calls for countries around the world to work out some type of nitrogen management agreement to help prevent this problem from reaching crisis levels.

Temperature

Temperature always influences fertility. If a lake is cold, a high nutrient loading may fail to make it eutrophic. A relatively high influx of nutrients from the watershed is locked into the toxic mud under an oxygen-rich hypolimnion. A large volume of water implies a large oxygen reserve. Thus a very deep lake can retain oxygen in the hypolimnion all summer, even though the surface waters are fertile, and deep lakes can retain the essential properties of oilogotrophic lakes despite significant nutrient loading from the watershed (Colinvaux 1993). The high water temperatures that excluded certain zooplankton species, and the inedibility of the filaments, further increase the dominance of cyanobacteria. The discharge of sewage and drainage water has resulted in the change in temperature, pH, and metal concentration in many wetlands.

Dissolved Oxygen

Dissolved oxygen is an important indicator of the environment's water quality. It is vital to the existence of most aquatic organisms and there are many factors that affect the concentration of dissolved oxygen. The minima and maxima in the concentration of dissolved oxygen are found to be directly related to the maxima and minima of the phytoplankton. Slight variations in the relationship of dissolved oxygen and phytoplankton in winter is attributable to the lowering of water temperature. This in turn increases the capacity of water to hold more dissolved oxygen, possibly due to the decreased photosynthetic activity of the phytoplankton brought about by temperatures beyond the optima. This would otherwise act as a limiting factor for photosynthetic activity (Kant & Raina 1990). The direct relationship between phytoplankton and dissolved oxygen content has been observed by a number of researches. Other factor also includes temperature, stream flow, air pressure, aquatic plants, decaying organic matter, and human activities.

pH

The measure of pH in a body of water is a very important indication of water quality. Water with a pH value of 7 is neutral. A decreasing value in pH indicates that the water is slightly acidic, while an increasing pH value indicates that the water is basic. The expected pH value of streams and lakes is usually between 7 and 8; however acid rainfall may alter pH values to become more acidic. Bicarbonate ions from lime deposits may also react with water to produce a more basic solution.

Engineering Aspects of Eco-Sub

The engineering design of Eco-Sub was driven by the scientific demand of the project. The main goal of the Eco-Sub is to design an inexpensive underwater enclosure that is capable of withstanding underwater pressures without doing any harm to the interior breach of the main body of the enclosure. Simultaneously the Eco-Sub can record data, using a data logger and probes (Nitrate, Dissolved Oxygen, pH and Temperature).

For the initial stages of Eco-Sub, the design was simple and straightforward. The majority of the parts were bought from two companies, McMaster-Carr and Grainger. Any technical drilling and fitting of particular parts was done in a machine shop on campus. The ultimate goal for Eco-Sub in its final form is to resemble an actual submarine that can maintain depths of 400 meters or more. Also it has to sustain under water suspension for multiple hours at a time until disturbed by an activity of interest that merits recording graphically. Until the final advancement of Eco-Sub, the underwater enclosure will continue with moderate progression towards plausible goals one step at a time.

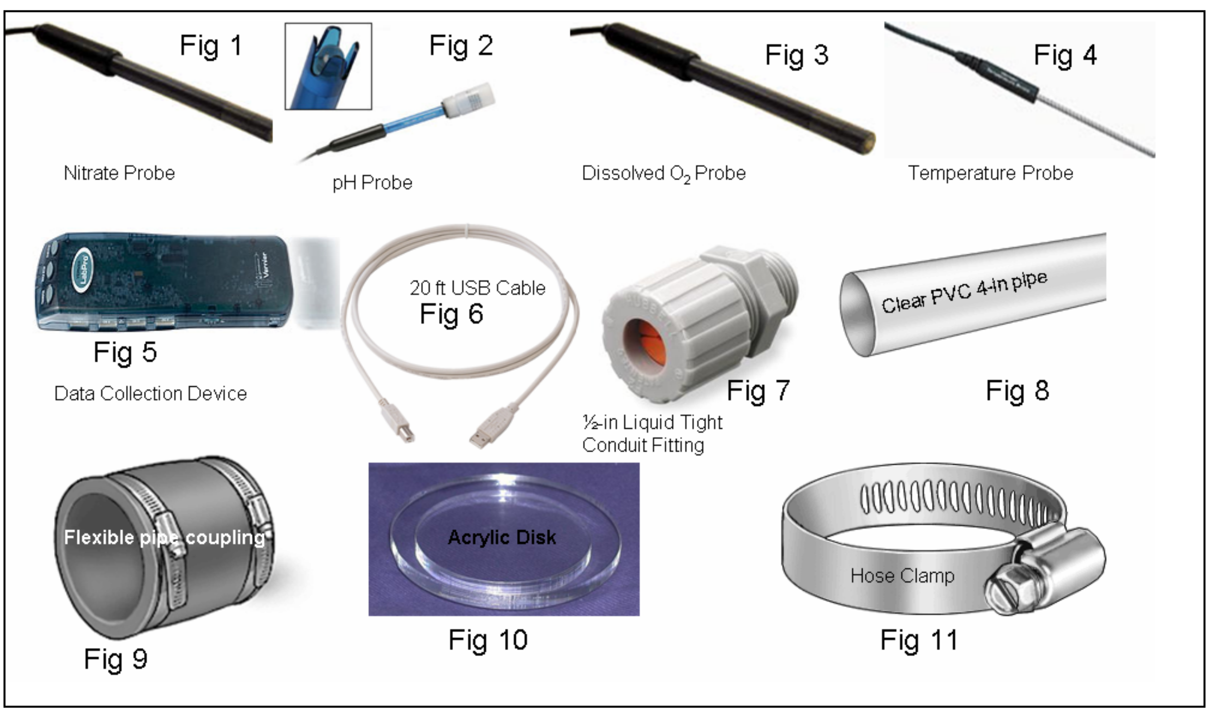
The components for Eco-Sub were either purchased on a credit card or through a purchase order from Cal State LA. The materials that were purchased took a minimum of two to three days for home delivery. The physical manifestation of Eco-Sub was easily assembled once parts were obtained from McMaster-Carr. A method of pre-drafting was employed using, Solid Works, a drafting program employed by engineers and architects.

Once the materials were gathered and the final design of the submarine was finished, the Eco-Sub was fully assembled. The following Table below lists items used in the making of Eco-Sub along with their matching item numbers as used by McMasterCarr:

No	Quantity	Description	Part No.	Price
1	1	Dissolved Oxygen Probe	DO-BTA	$199.00
2	1	Nitrate Ion Selective Probe	NO3-BTA	$169.00
3	1	pH Sensor	pH-BTA	$78.00
4	1	Stainless Steel Temperature Probe	TMP-BTA	$29.00
5	1	Data Collection Device (LabPro)	LABPRO	$220.00
6	1	20 Feet USB Cable	#J2PCPHRR USB-20	$39.95
7	1	Liquid Tight Conduit Fitting ½” (Hubbell) from Grainger	5D885	$6.82
8	1	Std Wall (Schedule 40) Clear PVC Pipe 4” Diameter Pipe Size 4’ Length	49035K33	$93.86
9	2	Gravity-Flow Flexible pipe coupling straight 4” Pipe Size, 4’ Length	4511K82	$13.00
10	2	Clear Cast Acrylic 6” Diameter ½” Thick, 6” Diameter	1221T39	$26.70
11	1	316 SS Worm-Drive Hose & Tube Clamp 4-1/8” to 7” Clamp ID Range, 9/16” Band Width Packs of 5	5011T74	$12.68

Table 1

Displayed below are the illustrations of the parts needed for the assembling of Eco-Sub.

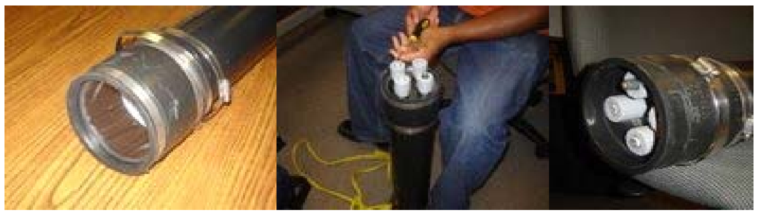


Step 1. Purchase the following components (Figures 1 to 10 corresponds to items 1 to 10 from Table 1).

Figure 2. Overview of the components (Figures 1 to 10) used to integrate the EcoSub.

Step 2. Take the clear acrylic disc and drill four 1/2" diameter holes in the disc, this allows the," Liquid Tight Conduit Fittings, (LTCF)" to be inserted in. [Note: take a measurement of the diameter of the part of the LTCF that will be inserted in the disc,], before drilling. Once the LTCF have been inserted in the acrylic disc, take each probe and inserted it in the opening of the LTCF.

Step 3. Take the clear PVC pipe and slip one of the pipe coupling on one end of the pipe. The open end of the clear PVC pipe will allow the entrance of the data collecting device which will be connected to the probes that was inserted through the LTCF. After one coupling is situated firmly around the clear PVC pipe., take a hose clamp and slip the clamp around on the coupling that is already situated around the clear PVC pipe. There should be a grove imprinted on the coupling that will allow the proper fitting of the clamp. Make sure that the clamp is nested around this grove. Then take a flat head screw driver and begin to tighten the clamp until the coupling is situated properly. Repeat this process again for the second grove imprinted on the same coupling. When the clamps are properly tighten the coupling should not allowing any leakage.



Step 4. Obtain a data collecting device (also known as data logger) with batteries and the necessary test probes. After acquiring the data logger and test probes, connect probes into appropriate ports on the data logger. Slip on the second pipe coupling and use the hose clamp to tighten appropriately using a flat screwdriver.

Step 5. Tie a rope and now is ready for deployment and have fun.

Experimental Methods

The Eco-sub device was first deployed in the Whittier Narrows Lake at the southern boundary of the San Gabriel Valley, in the Los Angeles County in California. It is a gap in the Puente Hills where the Rio Hondo and the San Gabriel Rivers converge. This area covers over two hundred acres of natural woodland including four lakes that provides a winter sanctuary for migrating waterfowl and houses a variety of animals. Water quality data was taken at 13:09 for 3 minutes at a 30 seconds time interval. Additionally, the water testing is also performed at four different locations to obtain an average concentration of the four parameters present in the lake. The second submarine test was conducted in the Ballona Watershed. It is the largest watershed draining to Santa Monica Bay and the area covers approximately 130 square miles and it provides habitat for threatened and endangered species, including the Belding Savannah Sparrow and the California Brown Pelican. (Ballona Wetlands Enhancement Planning 2) Water quality data was conducted at the Ballona salt marsh at 19:34 for 10 minutes at a 20 seconds time interval, and the third data was collected at 10:08 for 10 minutes at a 20 seconds time interval in the Ballona creek

Results

Readings from the Whittier Narrows Lake average about 7.0 to 8.0 for pH values; 8.5 for dissolved oxygen levels; 32.6 degrees Celsius or 90.7 degrees Fahrenheit on surface water. Nitrate levels in the area average about 1.0 mg/L and are considered not harmful to aquatic life according to the water regulation of Los Angeles County Water District.

Table 1.1

	Dead Frog Area			
Time (s)	*NO_3	Temp	DO	pH
0	1	32	9	8.6
30	1	32.7	9	8
60	1	32.7	9	8.5
90	1	32.7	9	8.99
120	1	32.7	9	7.8
150	1	32.7	8	8.52
180	1	32.8	8	7.65

Table 1.2

Near Poop Area			
*NO_3	Temp	DO	pH
1	31.5	9.7	7.8
1	31.5	9.6	7.8
1	31.4	10.1	7.8
1	31.4	9.8	7.7
1	31.5	10.4	7.6
1	31.4	10.3	7.65

Table 1.3

		Waterfall		
Time (s)	*NO_3	Temp	DO	pH
0	1	18.8	4.5	6.54
30	1	18.7	4.6	6.93
60	1	18.7	4.7	7.04
90	1	18.7	4.7	7.17
120	1	18.7	4.7	7.16
150	1	18.6	5	7.22
180				

	Below Waterfall		
*NO_3	Temp	DO	pH
1	19.2	5.1	7.37
1	19.1	5.3	7.33
1	19.2	5.4	7.27
1	19.3	5.7	7.35
1	19.3	5.7	7.33
1	19.3	5.8	7.32

Figure 1.1

Figure 1.2

Figure 1.3

The second water quality test taken by the Ecosub device was conducted at the Ballona Salt Marsh in Santa Monica. Below are data collected from the Ballona salt marsh taken at 19:34 for 10 minutes at a 20 seconds time interval. Average reading of pH in this area falls between 7 and 8; the temperature of surface water average 18.58° Celsius; dissolved oxygen falls between 6.5 and 6.7 and nitrate levels is 1.0 mg/L.

Lab Test 08/01/07.cmbl 8/1/2007 19:34:19

Time sec	**pH**	**Temperature** °C	**DO** mg/L	**Nitrate** mg/L
0	8.08	18.64	6.71	1.00
20	8.07	18.67	6.70	1.00
40	8.06	18.64	6.69	1.00
60	8.05	18.64	6.69	1.00
80	8.05	18.64	6.67	1.00
100	8.04	18.64	6.68	1.00
120	8.03	18.64	6.67	1.00
140	8.01	18.64	6.64	1.00
160	8.00	18.62	6.65	1.00
180	7.98	18.62	6.64	1.00
200	7.98	18.60	6.63	1.00
220	7.98	18.60	6.63	1.00
240	7.98	18.60	6.61	1.00

260	7.97	18.60	6.61	1.00
280	7.96	18.60	6.62	1.00
300	7.94	18.60	6.61	1.00
320	7.92	18.60	6.60	1.00
340	7.90	18.57	6.62	1.00
360	7.88	18.57	6.60	1.00
380	7.86	18.55	6.59	1.00
400	7.84	18.57	6.59	1.00
420	7.83	18.55	6.59	1.00
440	7.83	18.55	6.58	1.00
460	7.79	18.55	6.58	1.00
480	7.78	18.55	6.60	1.00
500	7.77	18.55	6.60	1.00
520	7.78	18.55	6.58	1.00
540	7.77	18.53	6.57	1.00
560	7.76	18.53	6.57	1.00
580	7.72	18.53	6.59	1.00
600	7.72	18.53	6.57	1.00

Our third test using the Ecosub was conducted at the Ballona Creek, a creek that is separated from the salt marsh by a concrete boundary. The Creek collects ‘runoff from several partially urbanized canyons on the south slopes of the Santa Monica Mountains as well as from urbanized areas of West Los Angeles, Culver City, Beverly Hills, Hollywood, and parts of Central Los Angeles’. (Ballona Wetlands Land Trust) Average reading for nitrate in the Creek is 1 mg/L; 22.02 degree Celsius for temperature; 4.7 for pH, and 6.8mg/L for dissolved oxygen.

Ballona Creek Testing 8/14/07 10:08 AM .

Time sec	Nitrate mg/L	Temperature °C	pH	DO mg/L
20	1.00	22.20	7.18	3.84
40	1.00	22.10	4.40	7.31
60	1.00	22.59	4.25	7.17
80	1.00	23.64	4.22	7.00
100	1.00	23.78	4.21	6.57
120	1.00	23.55	4.22	6.44
140	1.00	23.45	4.26	6.52
160	1.00	23.66	4.26	6.63
180	1.00	23.66	4.28	6.95
200	1.00	23.66	4.32	6.82
220	1.00	23.48	4.39	6.83
240	1.00	23.38	4.43	6.65
260	1.00	23.03	4.59	6.91

280	1.00	22.71	4.62	6.90
300	1.00	22.43	4.63	6.99
320	1.00	22.27	4.34	7.03
340	1.00	22.20	4.52	6.94
360	1.00	22.10	4.36	6.94
380	1.00	22.08	4.46	6.70
400	1.00	22.06	4.53	7.14
420	1.00	22.03	4.35	7.12
440	1.00	22.03	4.32	7.18
460	1.00	22.06	4.28	6.97
480	1.00	22.29	4.27	6.82
500	1.00	22.50	4.25	6.86
520	1.00	22.64	4.25	6.72
540	1.00	22.62	4.32	6.83
560	1.00	22.27	4.36	6.76
580	1.00	22.13	4.55	6.81
600	1.00	21.94	4.53	6.89

Conclusion

Using the method and materials to build an unmanned underwater sensor (Ecosub) described previously, we are able to collect real time data and assess result from a body of water. Data collected from the Whittier Narrows demonstrate that the Lake had a higher dissolved oxygen level even at peak sunlight exposure than water present in the Ballona Wetlands area. pH readings are most acidic in the Ballona Creek when compared to pH values from the Ballona salt marsh and Whittier Narrows Lake that ranges between 7 and 8. This is due to runoff from several partially urbanized canyons on the south slopes of the Santa Monica Mountains and other urbanized areas that drains to the Ballona Creek. Temperature readings from all three testing sites correlate to the time of day when measurement was taken. Nitrate levels from all testing sites demonstrate the low quantity that is present in each body of water, and is considered unharmful to aquatic organisms.

Future Research

The goal of this project is to build an unmanned underwater sensor that will be used for water sampling in order to monitor pollution. The device will house a set of sensors that will record time and location when critical levels of nitrogen, oxygen and phosphorus are reached and when drastic changes of pH and temperature occurs. The device will be incorporated with a propulsion system that can be controlled wirelessly by a remote system. The submarine will stay dormant until a drastic change in any of the parameters is reached. When a change occurs, the device will detect and identify the major source of pollutant.

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