Remote Sensing of Water Quality of the Charles River

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Abstract

The feasibility of using satellite imagery for water quality studies of the Charles River between the Massachusetts Avenue and Longfellow Bridge was investigated. Turbidity (ground data) was correlated to the red reflectance band of two IKONOS images. The program, ENVI was used to extract red band values. R^2 values of .57 and .04 indicate that there is no correlation, implying that the use of satellite imagery for water quality measurements in this study area is not feasible.

Introduction

In 1995, the United States New England office of the Environmental Protection Agency (EPA) established the Clean Charles 2005 Project. The goal of this initiative was aimed at restoring the water quality of the lower Charles River, from Watertown to Boston Harbor, to a condition safe for swimming and fishing by Earth Day 2005. Under the Clean Water Act, the terms swimmable and fishable are the goals / objectives for all bodies of water in the United States.

The state of Massachusetts has proclaimed water quality standards relating to "fishable" that establish limits for dissolved oxygen, pH, and temperature. Limits for bacteria are set to meet standards for swimmablity. In addition, the state has promulgated standards that relate to both fishable and swimmable such as aesthetics, bottom sediments, radioactivity and toxics.

Since the project's establishment, the EPA has made numerous steps /advances to meeting its goals. Focuses for water quality improvements have been on combined sewer overflow reduction, illicit sanitary connection removal, storm water management, planning and implementation, public outreach, and water quality monitoring and assessment.

Today, in the year 2005, ten years after the initiative was implemented the Charles River received a swimmable/fishable grade of a B+ a vast improvement from the D it received at the start of this initiative. Criteria for grading is based on monthly water quality data obtained from the Charles River Watershed Association.

However, there are many concerns with the grading system, one being that the characteristic / parameters of the river tested are not accurately representative of the River at real time nor is the data always reliable. There is a need to find an alternative means for obtaining field measurements. Ground sampling is limited in numerous areas; as mentioned real time data is one factor and another is obtaining data at a consistent location or an area that otherwise would be inaccessible. Other restrictions with ground sampling are human and equipment errors. One alternative is using satellite imagery for water quality studies.

In 2004, F. L. Hellweger and colleagues at Columbia University conducted a research titled *Use of satellite imagery for water quality studies in New York Harbor*. In the research, Hellweger et al (2004) identified a correlation between turbidity, determined by secchi depth and the red

reflectance band of the Landset TM, which had an R^2 value of .85. In addition, Hellweger et al (2004) cited other bodies of water in which satellite measurements of water quality were compared to ground samples.

The current research focuses on the possibility of using satellite imagery for water quality studies of the Charles River, between the Massachusetts Avenue Bridge and the Longfellow Bridge by identifying a correlation between turbidity (ground data) and satellite imagery. In this paper the information on the data sources are presented, the steps taken to acquire the data are explained; analysis of the results are presented and finally conclusion and further recommendations are given.

Data

The main sources of data used in this research fall into two categories, ground and satellite data. Ground data such as dissolved oxygen, temperature, turbidity, chlorophyll a, fecal coliform, and total suspended solids readings were obtained from an excel file that contained data from 1998 thru 2003 complied by Massachusetts Water Resources Authority (MWRA) in conjunction with the Clean Charles 2005 Water Quality Reports prepared by the US EPA Office of Environmental Measurement and Evaluation. Twelve main (core) stations were monitored by the program, ten of which were located in the Basin (area between the Watertown Dam and the New Charles River Dam), one station located on the upstream side of the Watertown Dam and another located immediately downstream of the South Natick Dam. For this research, only the monitoring stations, within the Massachusetts Avenue Bridge and Longfellow Bridge, as represented by orange dots are analyzed (Figure 1).

Figure 1: Map of the Core Monitoring Stations between Mass Ave and Longfellow Bridges

Image Provided by Petr Masopust, Northeastern University Masters candidate

Spatial data was provided by the IKONOS (Greek word meaning image), a one-meter commercial remote sensing satellite, which was launched by the Space Imaging Company in September of 1999. IKONOS produces 1-meter black-and-white (panchromatic) and 4-meter multispectral (red, blue, green, and near infrared) imagery that can be implemented to provide high-resolution image data. Since the IKONOS can collect about 772 square miles of images per minute, it is a vital instrument in obtaining information on various Earth features such as fluctuations in land and water resources that are constantly changing.

Methods

Using the Environment for Visualizing Images (ENVI) program for its ability to extract information from images, rectangles were created around the locations of the core monitoring stations between the two bridges of interest as seen in Figures 1, 2 and 3, respectively. The two forms of data, ground and satellite were available only for the two dates, June 13, 2001 and September 26, 2001. The cloud coverage for both dates was reported at zero.

Figure 2: Satellite Imagery of Charles River on June 13, 2001

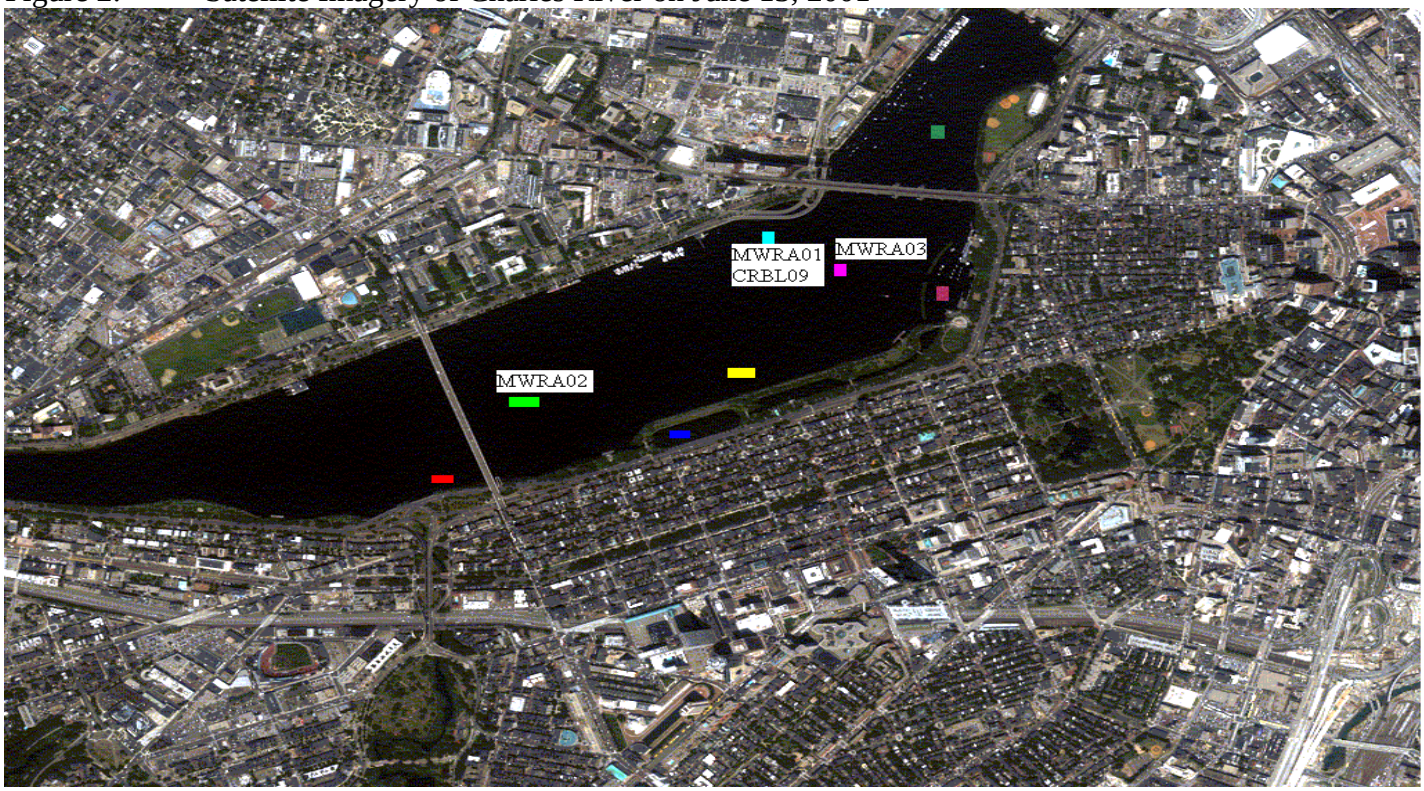
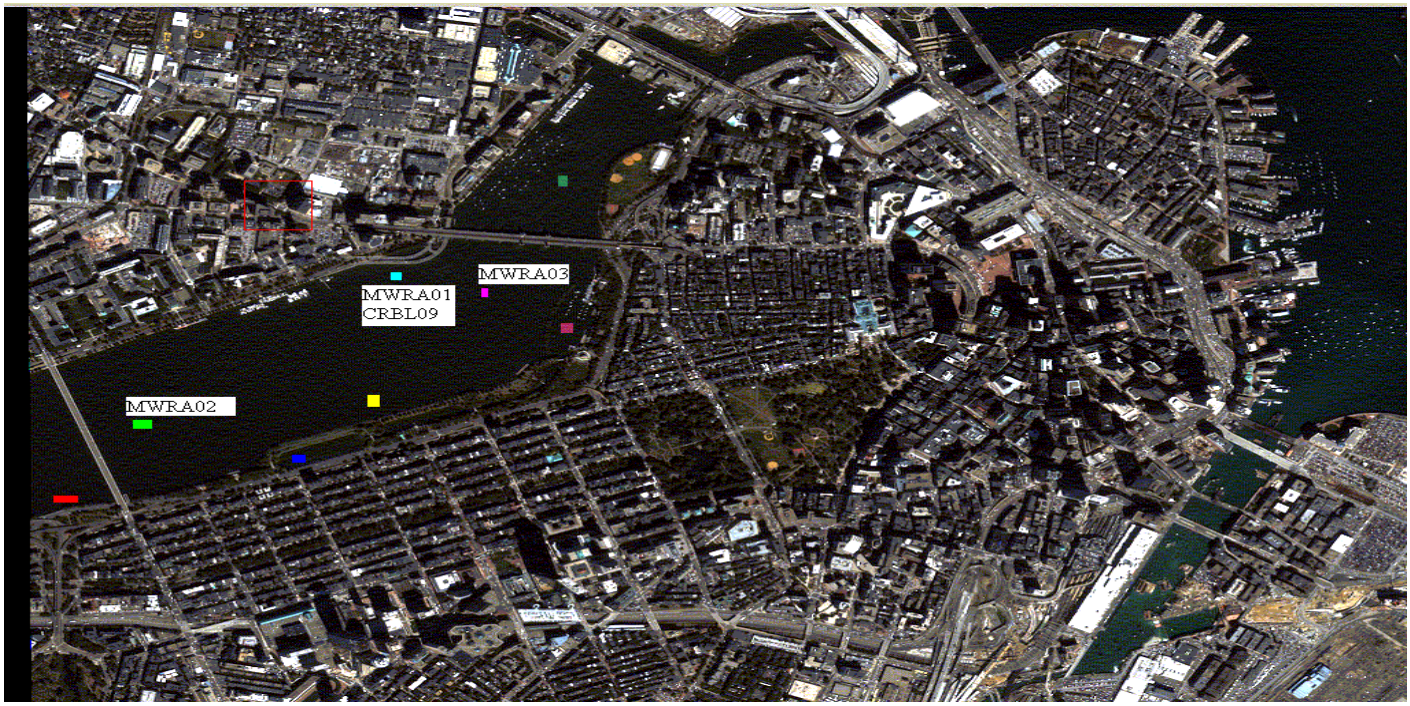


Figure 3: Satellite Imagery of Charles River on September 26, 2001



As seen in Figures 2 and 3, only three stations were identified. This is because out of the six stations located within the boundaries of interest these three are the only ones to have ground data taken on the two dates of interest. The three stations are MWRA01, MWRA02, and MWRA03. Station MWRA01 is located in Cambridge, near the Massachusetts Institute of Technology (MIT) Boat House. MWRA02 is monitored downstream of the Massachusetts Avenue Bridge near the midstream. Finally, MWRA03 is at the opposite side, upstream of the Longfellow Bridge at the center as well.

To ensure that rectangles were true representations of the selected area, color schemes were created to verify that there were no deviations in red band values within the regions. Below in Figures 4 and 5 is the color scheme map for Stations MWRA02, MWRA01, and MWRA03 on June 13 and September 26, 2001, respectively.

Figure 4: Color Scheme of Red Band Values of Stations on June 13, 2001

MWRA02

163	163	163	161	158	154	160	158	163	161	158	158	157	157	157	155	156	157	157	158	159	158
160	160	158	163	156	154	153	161	162	157	158	156	157	158	160	154	159	159	158	159	160	159
152	158	163	158	157	160	158	157	156	160	162	158	158	158	159	159	156	157	159	157	161	157
160	162	158	158	156	163	158	159	159	156	157	152	159	159	158	155	150	158	163	153	161	153
161	155	159	158	157	159	160	161	156	158	158	154	162	158	156	159	159	157	149	158	161	165
161	158	163	156	156	162	158	156	155	161	157	156	157	156	157	151	155	164	162	158	161	155
158	161	162	160	156	157	161	160	159	159	156	163	157	153	154	161	160	159	153	158	153	162
158	160	159	160	159	159	160	159	159	159	157	154	160	157	155	159	160	160	154	159	156	154
159	159	159	160	160	159	160	159	159	159	157	162	156	157	161	154	156	160	160	159	161	157

MWRA01

171	166	172	172	173	175	173	169	170
171	172	170	173	171	169	168	168	171
172	172	172	169	168	170	169	172	172
172	172	171	170	175	172	168	169	170
170	172	173	174	172	170	169	168	170
170	167	166	163	166	170	168	166	171
170	172	174	174	166	166	169	166	172
172	167	165	167	166	171	169	165	170
166	167	168	170	166	165	166	166	167
167	166	167	168	168	169	168	168	163
166	163	164	166	168	168	166	166	164

MWRA03

165	159	161	164	160	166	160	164	165
164	162	162	165	159	158	165	160	158
165	163	162	166	169	161	157	166	162
166	162	163	161	157	164	166	160	166
160	161	161	161	161	159	158	165	160
166	163	159	160	159	160	160	158	158
163	161	159	160	158	159	159	163	165
157	157	161	159	162	163	162	163	163
164	162	164	164	161	161	161	161	160
162	163	162	163	156	160	163	162	163
160	164	163	163	164	163	162	162	163

Color Range of Red Band

145-149 pink
150-154 rose
155-159 tan
160-164 light yellow
165-169 light green
170-174 light turquoise
175-179 lavender
180-184 gray -25%
185-189 gray 50%

Figure 5: Color Scheme of Red Band Values of Stations on September 26, 2001

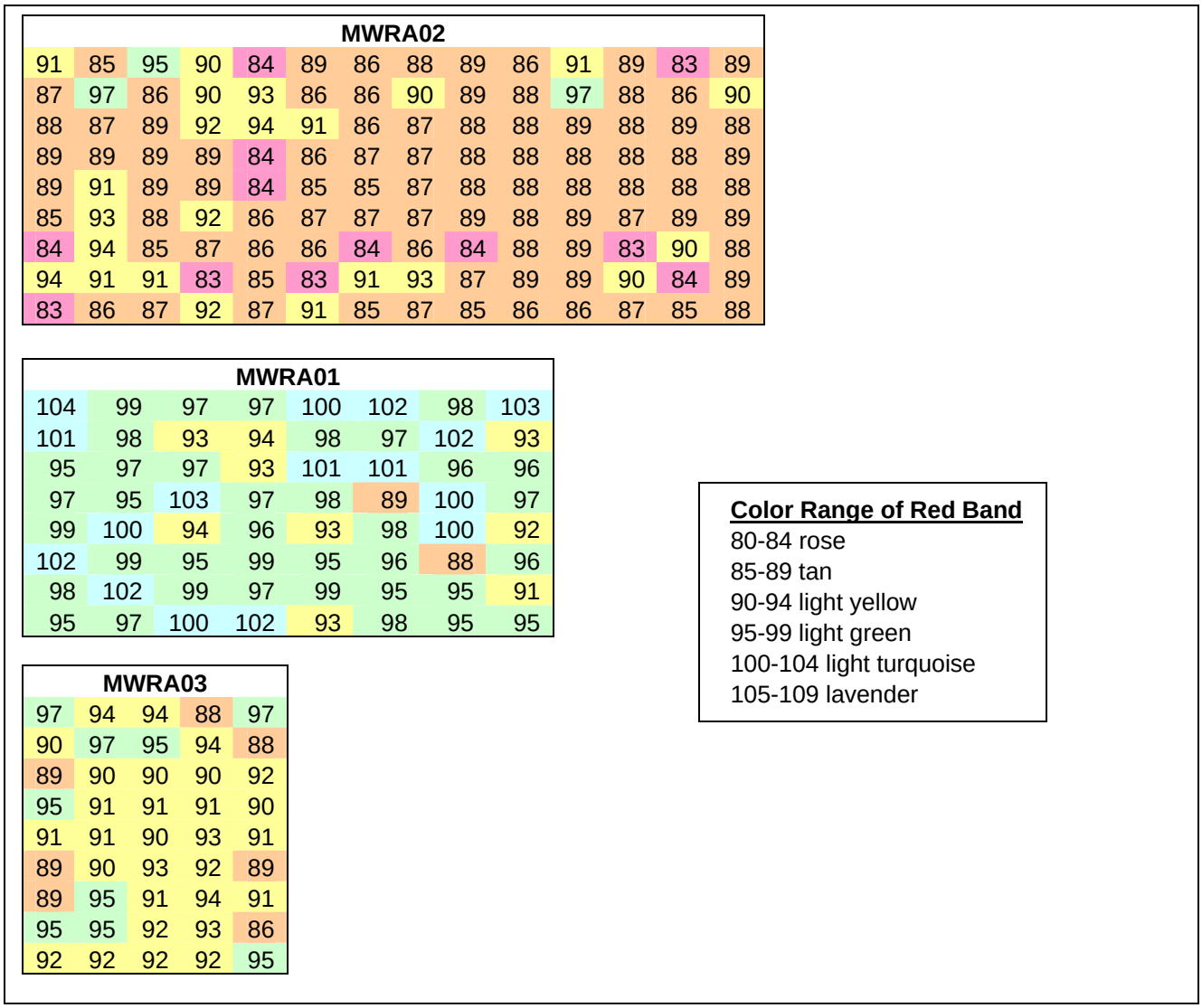


Table 1: Data for June 13, 2001

STATION	*DESCRIPTION*	*RED*	*TURBIDITY*
MWRA03	Upstream of Longfellow Bridge	162	9.2
MWRA01/CRBL09	Cambridge near MIT Boathouse	169	9.3
MWRA02	Downstream Mass Ave Bridge mainstream	158	9.7

Table 2: Data for September 26, 2001

STATION	*DESCRIPTION*	*RED*	*TURBIDITY*
MWRA01/CRBL09	Cambridge near MIT Boathouse	97	7.3
MWRA02	Downstream Mass Ave Bridge mainstream	88	7.5
MWRA03	Upstream of Longfellow Bridge	92	8.3

Results

Figure 6: Turbidity vs. Red Band Value on June 13, 2001

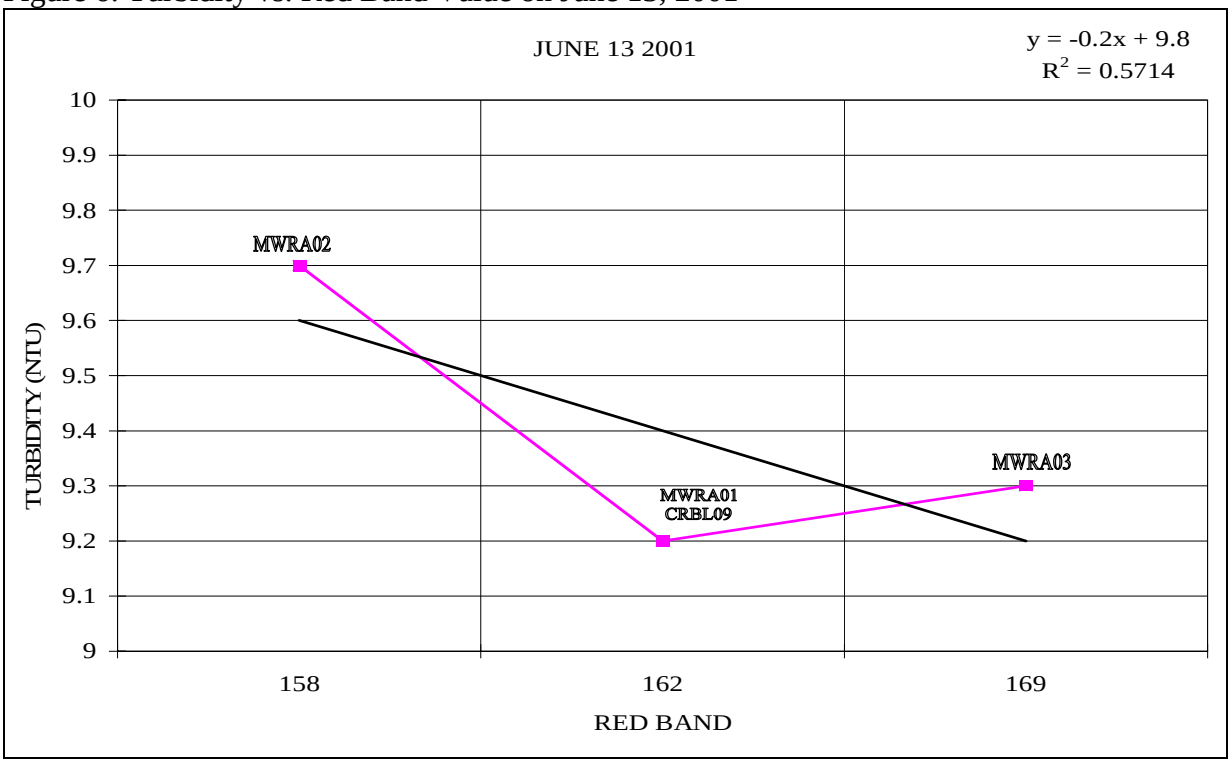
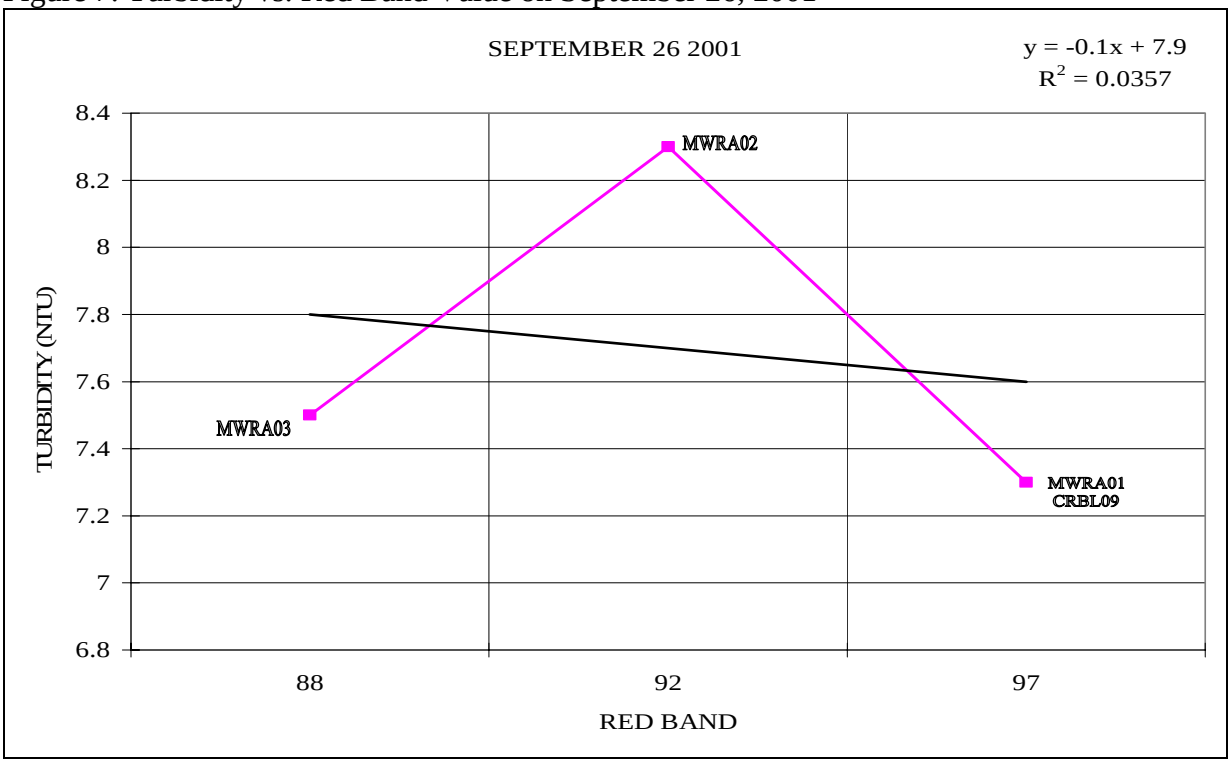


Figure 7: Turbidity vs. Red Band Value on September 26, 2001



Figures 6 shows that the correlation between turbidity and red band values based on a linear trend for June 13, 2001 is $y = -0.2x + 9.8$ and that the R^2 value is above fifty percent at 0.57. For September 26, 2001 as seen in Figure 7, the linear trend is $y = -0.1x+7.9$ and its R^2 value is only at 0.04.

Conclusion and Recommendations

In this study the possibility of using satellite imagery as an alternative measurement means for turbidity was not supported. The R^2 values of .57 and .04 for dates, June 13 and September 26 2001, respectively conclude an unreliable correlation between the red reflectance band values and turbidity. Which therefore indicates that satellite imagery, cannot be used to determine this particular water quality parameter between the Massachusetts Avenue and Longfellow Bridges.

Even though the feasibility of using satellite image for measuring turbidity, was not supported, a few reconsiderations must be taken into account. The first is that there were only three ground samples to analyze. Another concern was the actual locations of stations were not standard; there were no longitude or latitude directions to compare to the satellite images. In addition, the rectangles that were created to obtain red band values were done by sight, which introduces human error. Finally, satellite imagery only allows for characteristics of the surface of the water.

Further research possibilities include looking at comparing other water quality parameters such as total suspended solids, chlorophyll a, and secchi depth. In addition, correlation to other band colors or the ratio of bands can be investigated. Finally, further investigations will show if it will be possible to use satellite imagery for a day-to-day grading of the Charles River for swimmable and fishable conditions.

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References

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