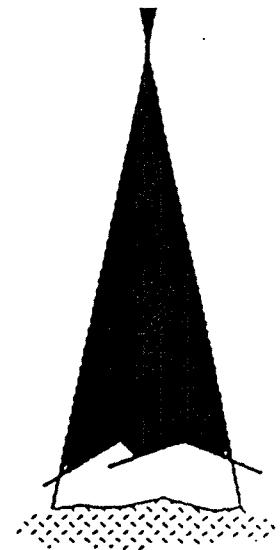


ENVIROSCAN

AERIAL COMPUTER ENHANCED WEED/POLLUTION MAPPING SERVICE



DEVILS LAKE AERIAL SHORELINE ANALYSIS

DEVILS LAKE IMPROVEMENT DISTRICT
NOVEMBER 1988

ACKNOWLEDGMENTS

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INTRODUCTION

As a result of man's activities in the watershed and shoreline development, many lakes are showing signs of progressively deteriorating water quality, which threatens the aesthetic, recreational and potable uses of the resource. Identification of potential sources of pollution and over enrichment to a waterbody is essential before control is possible. But determining point and non-point sources of contamination within a watershed or entering a body of water can oftentimes be difficult using conventional aerial or ground survey techniques. The need to document potential inputs quickly and accurately is crucial in the development and implementation of any watershed or lake management plan.

Aerial Shoreline Analysis (ASA) is a state-of-the-art remote sensing technique developed to detect and define potential pollution inputs to lake, estuary, and river systems in nearshore areas. ASA utilizes an aerial platform for data collection, that provide a more encompassing perspective of an area than that gained from ground level alone. The target shoreline is photographed in both the infrared and visible regions of the spectrum. Imagery data are analyzed for sources of contamination to the subject watercourse. More specifically, the methodology possible identifies point and non-point toxic, septic, runoff or other nutrient enrichment sources, effectively locating specific sites of suspected pollution for further ground truthing. The imagery data set generated by ASA provides a permanent record of current land use impacts on a waterbody that can be used for future comparisons.

Aerial Shoreline Analysis was conducted on selected shoreline areas of Devils Lake, Oregon. Objectives of this investigation were to provide Devils Lake Improvement District with a database that both identifies suspected pollution sites in nearshore areas of the lake and ranks severity of impacts on water quality. This information should be used by City staff to develop a ground truth sampling scheme to inspect specific areas of indicated pollution. Specific objectives of the investigation were to :

1. Conduct ASA on Devils Lake

2. Prepare a final report, including a complete set of imagery generated, tabulated analysis of each site, and a summary narrative describing general characteristics of and significant pollution sources detected.

We have endeavored to present the following technical information in a format that can be easily interpreted and applied by lake managers for enhancing the water quality of Devils Lake. The concise report is separated into a standard introduction, methods, summary results and discussion section, followed by a detailed results section containing tabulated data with location maps. In the methods section is a user's guide to aid in establishing a ground-truthing protocol. In addition, a complete set of infrared and visible slides are included.

METHODS AND MATERIALS

DATA COLLECTION TASK ONE

The data collection phase of the project included flight planning, flight operations, and processing of the imagery collected. The planning began in late Spring 1988 and continued throughout the summer due to weather conditions. Areas selected were for the most part developed lots with some serviced by on-site waste disposal systems, and were of concern to the lake management authorities. The entire lake shoreline was targeted for image collection in this case.

The data collection team obtained aerial section charts of the ASA target and operations area for flight planning and performed a preflight inspection of the survey areas. Flight planning for ASA programs included such factors as distance from the base of operations airport to the operations areas for calculation of fuel consumption and flight time planning, locations of the targeted areas, location of all obstructions to the data collection aircraft such as power transmission lines crossing rivers or lakes in the area, towers from television and radio stations in the general vicinity of the flight lines and an evaluation of airspace for controls such as Military Operations Areas (MOA's) and Military Training Routes, Low Level (MTR's). Also reviewed were all radio frequencies required for operations in the target area and all airfields that could be used for emergencies should any develop. All conditions that would have a possible impact on the data collection flights were highlighted on the operations aerial sections charts for review and use during operations.

A set of 7.5 minute quadrangle maps of all targeted shorelines were obtained for use in the flight and film catalog section of the flight planning. Sunlight conditions play a major role in overall effectiveness of the data collection missions utilizing the ASA camera system. From a planning standpoint, the target shorelines were plotted onto the 7.5 minute quadrangle maps and flight line and direction were plotted off shore on the same maps. These maps were used for the daily flight operations and as film cans logs.

The flight protocol for ASA mission requires that shoreline be filmed in both the infrared and color visible portions of the spectrum. Under the flight protocol, imagery was collected at the rate of approximately 10 frames per mile with each frame providing coverage of about 500 feet of target shoreline with a 20% overlap. In cases where the

aircraft encounters a sharp turn in the shoreline, the image collection is halted while the aircraft turns to a more accurate camera angle. In the data section of this report which follows, these turning points are evident when the same site appear from a different angle in the overlap.

DATA INTERPRETATION

Editing of the imagery involves sorting by ASA flight codes for location and correlation to the map position. Flight target maps, flight film logs, and imagery codes were utilized to determine the map position for each image collected. New 7.5 quadrangle maps were used and each image position was coded onto the map for use by the interpretation team. New codes were assigned to each image for use in the interpretation and final report. These codes depict map position and location. While the Task 1 codes on the imagery was used to keep track of locations which were photographed, the new code is a map position which is easier to use by the interpretive staff and the client. These coded positions began at the starting point of the filming on the lake and proceed counter clockwise around the perimeter. This code system uses 1 as the first position and proceeds through the end of the imagery in numeric order.

The ASA interpretation protocol reviews each position for a number of parameters and conditions. The imagery was viewed through the ASA Image Enhancement System (IIS) to get an overview of conditions at that map position and zoom in on suspected problem areas. This system will load imagery for up to three consecutive map position in both the visible and infrared so the technician can have a continual view of the target shoreline. The imagery was collected with a 20% overlap to ensure survey continuity. The IIS provides setting for 20X and 80X magnification which allows both an overview and a close up look at any suspect sites.

The first step in analysis was to review the visible image to get an overview of conditions at that position. Lake bottom type, patterns of aquatic plant coverage, beach type and patterns, type and level of development and other land use practices are observed. Any visible differences in natural patterns were noted. The infrared image was then compared to the visible imagery, and each lot on both images was observed for conditions that would indicate point or non-point source pollution inputs to the lake. The 80X feature is utilized to review suspected pipe intakes/outlets and other conditions in greater detail.

For each map position under review, comments were recorded on a data file, and each position receives a check under one or more of the headings below as a quick reference guide.

A-Nonpoint Septic

B-Point Septic

C-Nonpoint Runoff

D-Point Runoff

E-Nonpoint Toxic

F-Point Toxic

G-No Apparent of Nutrient or Toxic Conditions

The format for the data section is outlined below with a typical set of comments included.

Map Position	A	B	C	D	E	F	G	#HOMES	RATING
43	.			.				6	5

At the left center of this position and on the beach is a suspected septic seep area as noted by the wet pattern on the beach. This is a suspected nonpoint nutrient source. To the immediate left of this seep is a defined area of macrophytes indicating seepage into the lake at this site. To the left of this is a white house. At the left of this house is a large white, suspected drain pipe that should be investigated for point source contamination. The upland area is natural forested.

All reproduction of the imagery was produced in slide format for inclusion in the final report. All data files were printed by the processing computer.

Finally, rating of each map position was also assigned on a scale of 1 to 5. The individual number and the corresponding meanings of the ratings are presented below.

1. Little or No Observed Problem Conditions
2. Minor Problems Observed
3. Some Suspected Evidence of Pollution Input
4. Many or Major Suspected Pollution Inputs
5. Suspected Major Problem Site

The rating system provides a level of problem assessment and was used to classify noteworthy conditions. These assessment rankings can be used to target areas of greatest concern for further inspection, sampling and corrective measures. Ratings in the 1 or 2 range have minor or no observed conditions that would lead to pollution of the lake involved. 3 is a mid range rating indicating that suspect conditions were present. The

ratings of 4 and 5 indicate significant problems exist at that position that warrant further investigation.

The imagery is attached as an appendix to this report. Each image is numbered and the number will correspond to an image position on the map in the results section. This map shows each image position as well as providing the rating and pollution input information. The code is: Image Position Number-Type of Pollution Input (see codes above), Position Rating (see codes above). An example would be: D26-A,E,5. This would mean that that was image position D26, that there were suspected impacts from nonpoint septic and nonpoint toxic, and that the rating for this site is 5.

USER'S GUIDE

It should be noted that ASA analysis is performed by technicians that have a wide range of experience in water quality problem and aerial imagery interpretation. The findings that are listed in the results section are a summary of the analyst's opinion of what is occurring at each location based on evidence contained in the imagery. In some cases, this evidence may be explained by causes other than those suggested in the analysis based on local information. It is important to review this data and provide additional local input where appropriate. For example, in Position No. 28 there is an area that shows typical signs of toxic inputs in the linear form of an unvegetated bottom within weed beds, and the evidence of disturbed soils on the upland areas. From just the imagery this appears to be an area where something has leached from under the trees into the lake. It was suggested at the meeting where this imagery was presented to interested parties that there had been a boat house that probably had been removed from this location. That would also explain the condition that is evident in the imagery. This type of input is critical in the end use of this imagery. As it is reviewed by local user groups, some of the conditions described will have simple explanations, but the majority will be suspected input sites.

The Aerial Shoreline Analysis data presented in this report should be used by the ground truthing team in the design of sampling methods aimed at quantifying nutrient and toxic loading into the waterbody in question. The first step will be to identify what sites to visit and how those sites should be sampled. For quick reference the first two lines of each image description identify possible types of pollution occurring at that location and also state the relative amount of evidence of contamination that can be defined by ASA, as

discussed above. Thus the sampling team will know if simple grab samples for nutrients will be most appropriate or if more sophisticated equipment and sampling regimen are required. For instance, is the source of pollution point or non-point pollution? For, non-point nutrient addition from septic sources is far more difficult to sample and define than is a piped effluent.

Another use of the ASA data is the estimation of types of water quality problems that a manager or regulating agency may have to deal with if water quality is to be maintained and/or enhanced. It can be determined by assessing whether a lake or river is being threatened by non-point runoff due to development pressure or if the use of on-site waste disposal is contributing to the loading of nutrients in unacceptable levels. It will also enable an agency to conduct an effective public education program to inform citizens of problems for which they as users of the system may be responsible. Watershed do's and don'ts are easily illustrated by comparing results of particular activities with contrasting practices. As an example, impacts on water quality due to over fertilization of lawns and gardens could be compared with non-impact yard practices.

DISCUSSION

Collection and processing of aerial imaging for Devil's Lake was relatively time-consuming for a number of reasons. Several separate aerial missions were required to adequately collect imagery of the lake due to problematic weather conditions that complicated data collection. Also, delays were experienced in outside laboratory processing of infrared imagery.

The overall data that appears on the imagery collected for Devils Lake were quite good. ASA Methodology identifies areas of suspected point and nonpoint runoff, septic, and toxic conditions. Point source inputs are identified as those that originate from a pipe discharging into the lake. Nonpoint sources are those that show evidence of impacting the water quality of the lake, but flow from the source toward the water across or below the sediment surface. The only point discharges that were observed were from nonpoint storm water drainage effluents pipes. Straight pipe discharge from septic systems were not the evident at Devils Lake. There were however a number of areas identified that should be checked for suspected inputs of pollutants of a nonpoint source nature. This discussion will focus on the type and location of major impacts to the lake. The suggestions as to the type of impact on the lake should be used in future planning of remedial action.

Runoff conditions are evident in many areas of the lake. As a lakeshore community becomes increasingly more urban, and density of homes and buildings increase, the influence of stormwater runoff can play an increasingly important role in contributing nutrients to a lake system. With the advent of more development in the watershed, the possibility of more contaminants entering the lake is increased. As the lake is the low point in the watershed, over time any pollutant that is introduced into the system has the potential to move to the lake. The increased level of development also provides a more direct flow of water over impervious additions to the watershed. Many of the contaminants that would normally be filtered out by riparian vegetation and movement through the soil profile now move directly to the lake via surface water runoff. With this natural filtration removed, this flow directly contributes nutrients and toxics to the lake.

In the imagery collected for Devils Lake, there is considerable evidence of this type of overland flow pattern on developed portions of the lakeshore particularly along

the western shoreline. Specific instances are noted in the results section presented in the back of the text. In many cases, there is street runoff that flows directly into the lake. In addition, there is some evidence on the imagery that septic systems located on the lakefront can provide nutrient inputs via this route, as septic problems are indicated with patterns of nutrients migration into the drainage ditch systems that lead to the lake.

Septic systems serve a large number of homes on the Devil Lake Watershed, both in the nearshore and upland areas. The impact from septic systems on lake environments comes from two different perspectives. In cases where there is direct hydraulic failure of a septic system, there can be flow of both nutrients and pathogens into the lake from nearshore homes. In these cases, the drainfields will show up on the collected imagery in a couple of different ways. If a drainfield experiences hydraulic failure, septic leachate is forced into the drainfield in excess of the field's ability to handle the water volume resulting in a hydraulic failure that leads to leachate flow on the ground surface. Prior to the occurrence such a condition, ASA Imagery shows highly enriched areas in linear patterns in the drainfield area. Mortality to lawn areas over the drainfield can occur in extreme cases. Increased availability of nutrients as the septic leachate moves into the root zone of the grass will lead to luxurious growth in minor cases and actual death from nitrogen toxicity in extreme cases. These patterns will also continue to the lake in cases of extreme failure. There is evidence of this type of failure in the imagery that was collected for Devils Lake at certain sites, and these are pointed out in the results section.

In other cases where older systems are located near a lake, just above the water table, there can be a dramatic inflow of nutrients to the lake through ground water even if the system is not hydraulically failing. The lake edge intercepts and is an extension of the ground water table in the soil around the lake. This ground water table will follow the geology of the soils as it moves away from the lake, but in most cases, the on site sewage (septic) systems of shoreline homes are located very close to the ground water table. With a limited depth of the soil profile over the water table, these shoreline homes may over extend the capacity of the soil to cleanse waste water.

The key nutrients to control in lake management schemes are phosphorus and nitrogen. Nitrogen moves fairly well through the soil and can move right through a drainfield into the ground water if the drainfield is located too close to the water table. This will effectively provide a route of input to the lake by ground water movement.

Phosphorus is another by-product that will have a dramatic impact on the trophic state of the lake. Phosphorus is the key nutrient in most lake restoration schemes, because it is the limiting nutrient to aquatic plant production in the lake. By limiting phosphorus inputs to the lake, plant growth can be reduced over time and lake water quality improvements can occur.

An average family inputs about 10 pounds of phosphorus to a septic system each year. Phosphorus can enter the lake as result of conditions of direct failure as mentioned above, or by overloading bonding sites in the sediment under the drain field. Phosphorus is removed from septic effluent by adsorbing to charged sites on clay particles in the sediment profile. P is normally not mobile in soils because it has a high negative charge that will attract to the positive charged sites on soil particles forming a tight bond. When a system has been in use for an extended period of time, and the location of the septic field is near a lake or the ground water table limiting the amount of soil the waste water flows through before reaching the ground water, the sites available for P bonding can be used up over time. When the soil runs out of charged sites to bond Phosphorus, it will move into the ground water and flow toward the lake. Patterns that indicate this type of flow often appears in the aquatic plant beds offshore. At the point where the ground water table with a significant phosphorus load intersects the lake bed, aquatic plant growth is excessive and is distinctly banded. In extreme examples, this macrophyte banding can be traced direct by to the drainfield of the home situated on the adjacent lot. Under this condition, a septic system can be providing efficient treatment of waste water in terms of pathogens, and bacteria, but be moving nutrients directly into the lake. Phosphorus can flow into a lake even when a septic system works well if the sites in on the soil particles in the drainfield are taken with other charged particles. Soil types will also play a role here. Sandy soil will increase the flow of water through the soil, and limit the number of bonding sites for charged particles further. In many cases around Devil Lake, the soil types appear to have a considerable amount of sand in the mix.

A considerable number of sites portrayed in the imagery collected for Devils Lake show evidence of this type of introduction. Sites showing evidence of ground water movement are indicated on each of the image positions. This source of input to the lake could contribute a significant amount of the nutrients flowing into the system on a yearly basis.

As the City is considering options that would include the addition of sewer service to some of the outlying areas of the lake shore, both forms of enrichment from septic systems should be taken into consideration. As the majority of the homes on the lake are older, there could be considerable movement of phosphorus into the lake from systems that are not hydraulically failing. A number of these suspect locations are pointed out in the results section. It should also be noted that the ground water table is indeed very close to the surface, limiting the area that is effective in waste treatment on a majority of the nearshore lots. On the West Shore of the lake, there are a number of sites that show evidence of ground water flow into the lake from the bluff, with very little area for effective water treatment. Other problem areas are the peninsulas. These are highly developed, and there is very little relief from lake level to the highest elevation on these features. This would leave very little sediment profile available for waste water treatment and P bonding, and there is ample evidence on the imagery collected that there are problems in these areas. Both of the peninsula areas should be targeted as a high priority area for further evaluation based on ASA analysis.

Toxic inputs to lake environments have an impact on the overall water quality of the lake, and in extreme cases, endanger plant and animal life in the lake. Smaller toxic inputs to the lake such as those identified in the results section normally do not have the overall impact on total lake water quality that excessive nutrient loading will have, but they can be very damaging in the local area near input sites. These conditions are normally detected on the imagery as areas where there is an abnormal amount of dead vegetation or buildup on the lake bottom that is not in line with the baseline growth in that area. When this type of pattern occurs and is detected, it is analyzed in greater detail to determine if some type of correlation occurs with any other portion of the imagery.

The majority of the areas that have been identified as potential toxic sites in the results section seem to be associated with potential runoff or storm drain input sites to the lake. These channels or pipes could carry chemicals and other materials that are potentially damaging to aquatic plant life. When compared to septic and runoff inputs described in this report, the toxic inputs for this lake are minor and the effects quite local. These conditions should be examined as time warrants.

shows toxic effects along the shoreline and possibly into the water. Dead vegetation both on the bank and in the inside of the dock line are indicators of toxic conditions. This property also has substantial areas in the back yard that are exposed dirt with some garden activity present. This would be a runoff source as well for applied fertilizers and pesticides because of the lack of vegetation between the water and the exposed areas. There is evidence of nutrient movement in the drainage ditch that moves along the road leading to these shoreline homes on both the IR and color imagery. The two homes to the right of house 1 on this image show some indication that nutrients are moving to the lake possibly from a drain field. Many of the second tier of homes in this position show evidence of nutrient movement toward the lake as well.

D6	A	B	C	D	E	F	G	#HOMES	RATING
			•					16	3

A number of homes in this position show evidence of enrichment in the form of over-fertilization. Most notable are the levels present in the IR for the house on the left of the point at the entrance to the small cove. The homes in the cove are covered on an additional image position. On the right of the canal mouth is an area that is made up of exposed earth. This would be a source of sediment input to the lake during runoff periods.

D7	A	B	C	D	E	F	G	#HOMES	RATING
			•					12	3

This position is a close-up of the cove area that is pictured in position D6. There are 12 homes in this cove and these are included in the 16 homes recorded for D6. There are points on both sides of this cove where street runoff directly accesses the lake and would contribute nutrients and contaminants such as oils to the lake during rain events. The majority of these homes have landscaping that is well suited to lakeside environs. The lawns stop well short of the waterline and in many cases the homes use products like bark and gravel to landscape. That will reduce the input of fertilizers from these homes. However, the bark will contribute salts. The cleared lot on the right of this position on the point of the cove shows signs of toxic conditions. There are patterns on the pavement of the road draining across this lot to the lake. Where these patterns move from the pavement to the lot, the vegetation is absent. There are a number of piles and tires on this lot indicating that materials may have been deposited here. As dead vegetation occurs from these piles to the lake, they should be checked for toxics.

D8	A	B	C	D	E	F	G	#HOMES	RATING
			•					1	4

This position is dominated by lots cleared for development on the lake shore. There are several roads ending in cul-de-sacs in this image. Each of these is providing a runoff channel capable of moving materials to the lake. Both of these areas show distinct signs of runoff down the road and across the cleared lot at the lower portion of the image to the lake. The

circle on the left and above the shoreline shows evidence of oil deposits on the color image. Runoff moves from that point down and into an area that is cleared for construction to the next road end. From that point there is very clear evidence of sediment movement and erosion toward the lake. At the shore line, this water flow causes bank erosion, and deposits in the lake are visible. The lawn at the only home on the shoreline in this image position shows signs that are typically associated with a drainfield, note the lines in the lawn on the IR image. Between this home and the lake is an area that has been cleared. The exposed dirt is different from the surrounding geological formation indicating that it has been brought in for fill, or that it has been treated.

D9

A	B	C	D	E	F	G	#HOMES	RATING
.		.	.				4	4

This position shows the home described in D8 to the left of the image, one new home site in the center and 3 older homes on the right of the image. The home described in D8 has a number of areas on the inshore lake bottom that indicate fill material is moving into the lake during runoff. The next home to the right of this is under construction and the shoreline is tree-covered. There is a point source runoff area that originates under the trees on this lot and leaves deposition on the lake bottom moving to the right in a narrow band. This should be checked. The three homes to the right of this are older in construction and show evidence of drainfields that are in various stages of repair. The center home, blue and grey with a small peaked roof shows an area both on the IR and Color image that would indicate a failing system. The lawn appears dead and forms distinct H shaped patterns moving from the house. Excessive nitrogen often has this effect in failing drainfields. There are patterns on the lake bottom offshore of this home and the house to the right of it that indicate organic runoff entering the lake.

D10

A	B	C	D	E	F	G	#HOMES	RATING
.							6	5

This image shows the conditions described in D9 at the three homes in the left of the position. There is also a very evident band of macrophyte growth parallel to the shoreline in the area that would indicate subsurface movement of nutrients from the ground water into the lake. This area may be a source of septic inputs to the ground water. Each of these homes shows some evidence of organic build-up offshore in plume type patterns.

D11

A	B	C	D	E	F	G	#HOMES	RATING
.		.					3	4

This image has overlap from D10 on the left beginning at the trailers, and is dominated on the right by a large public access. There is organic deposition at the lot line between the trailers and the home to the right. Plant growth in that area would indicate nutrient inputs here. Moving to the right, the cove that is present is eutrophic beyond baseline levels of the lake in this area. Aquatic plant growth is excessive indicating input of nutrients at this location. There may be a stream or runoff impact here adding nutrients to the system. The IR image shows excessive fertilization of the lawns adjacent to the access. The set up of the

pavement in the access area allows direct access of runoff to the lake. The area on the lake bottom adjacent to the grey boat house shows a considerable amount of organic build up that is different from baseline conditions. There may be a runoff point from the road that runs behind the trees contributing to this deposit.

D12	A	B	C	D	E	F	G	#HOMES	RATING
	•		•					4	3

There are three homes and a trailer that dominate this position. The shoreline is steep and there is minimal lawn development at these homes. Emergent vegetation is growing in along the shoreline. The home next to the trailer may have some septic problems. Digging is evident in the color image appearing in the back yard of this home as straight line patterns. This area is red in the IR image. There is also evidence of runoff from the streets moving across the two lots at the trailer and the home to the right that may be impacting the lake.

D13	A	B	C	D	E	F	G	#HOMES	RATING
			•					5	3

These homes are on steep banks with limited use of landscaping. The offshore weed patterns would indicate that there is limited movement of nutrients through ground water. The lot with the A frame to the left of this position and the home to it's right show signs of runoff patterns from the surrounding uplands. Both lots have areas that are not vegetated contributing to this type of flow. There have been aquatic weed control efforts targeted toward the water lily growth at the new beach area in the center of the image.

D14	A	B	C	D	E	F	G	#HOMES	RATING
	•		•					7	4

The shoreline is heavily developed at this position. There is a pattern that should be investigated in front of the trailer in the left of this position. The lower level of this lot has a pattern that may be associated with a failing septic system as the vegetation is growing excessively in a linear pattern toward and into the water. There are organic deposits offshore from this line. The lots to the right of this trailer have areas that are not vegetated and could contribute sediment to the lake during storm events. The barge that is providing pile driving services has a number of oil barrels on the deck and evidence of spills on the deck. It could be checked for oil containment equipment.

D15	A	B	C	D	E	F	G	#HOMES	RATING
			•		•			6	4

This position is dominated by a cove with a wetland in the background and a grass carp exclusion structure in the lily bed centered in this cove. This area is highly productive and above baseline levels for this portion of the lake. Filamentous algal growth is heavy against the shoreline indicating nutrient inputs at that point. There may be a stream that contributes to the nutrient loading of the lake at this location in the back

